GENERAL MOTORS
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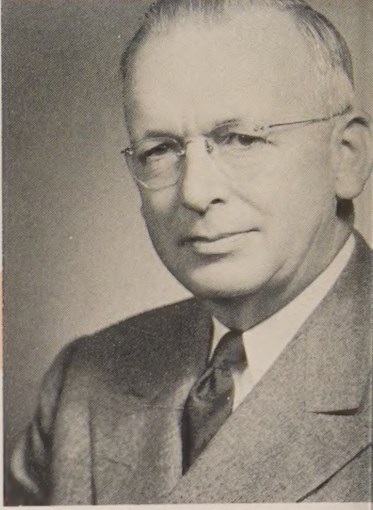
Volume 1 September-October 1953 Number 2

UTION OF THE WHEEL

GM



Some Thoughts on Research

INDUSTRIAL RESEARCH, like engineering education, is a process of learning. As such, it makes use of inanimate physical materials, mechanisms, and recorded scientific facts. The same inanimate things are requisites to an individual's educational growth.

In research, as in education, *things* are subordinate to the greater values which spring from the questioning attitude of *people* and their desire to learn. Neither elaborate equipment nor well appointed laboratories can think. These inanimate things make research possible, but creative values from these things can result only from the questioning, analytical minds of men.

Suppose an engine requires a better bearing. Research scientists build a test fixture to duplicate engine conditions. Then they install and operate various bearings on the fixture. The fixture helps to sort out the good from the bad—but cannot ever, by itself, develop a better bearing. Research workers call on their store of knowledge and their intelligence to interpret what the tests try to tell them. They learn from the inanimate but the language of the inanimate requires interpretation before the findings can achieve the desired result—a better bearing.

In many valuable types of work men apply only their store of facts. Lathe operators study blueprints and use acquired knowledge and skills to turn out finished pieces according to designers' plans. Research workers go beyond their store of knowledge and their acquired skills. Their work frequently begins where the area is uncharted. Often they do not know whether a solution exists; no previous experience can guide them. Things and facts they have learned are but props; the real work must be done in their minds.

Research inherently tries and fails again and again. One cannot acquire a grand piano in the forenoon and play Grieg's *Piano Concerto in A-Minor* before a critical audience that afternoon. Both the research worker and the musician need to practice: try and fail again and again until the musician achieves perfection and the research worker's last effort proves successful. Industry cannot accept major failures in its products or processes after they leave the laboratories; the musician cannot tolerate his own ineptness after the recital curtain rises.

If industry can afford failure, it is in the research laboratory. One basic new discovery can support many unsuccessful attempts. From the hard earned successes come tomorrow's improved products and processes.

C. L. McCuen

Charles L. McCuen
Vice President and General Manager
Research Laboratories Division

THE COVER

The cover is the first of a series on the development of transportation. Here artist John B. Tabb has used the gouache technique to illustrate the evolution of the wheel from a rolling log to its present mass use on automobiles. The steps portrayed include the log and wheels for an early Babylonian 4-wheel chariot, Egyptian chariot, a Roman chariot, an 18th century wagon, and an early 20th century automobile. The hub of the featured present-day automobile wheel illustrates one step in mass production techniques which make the wheel possible.

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The Work and Contributions of a GM Division (Second in a Seri

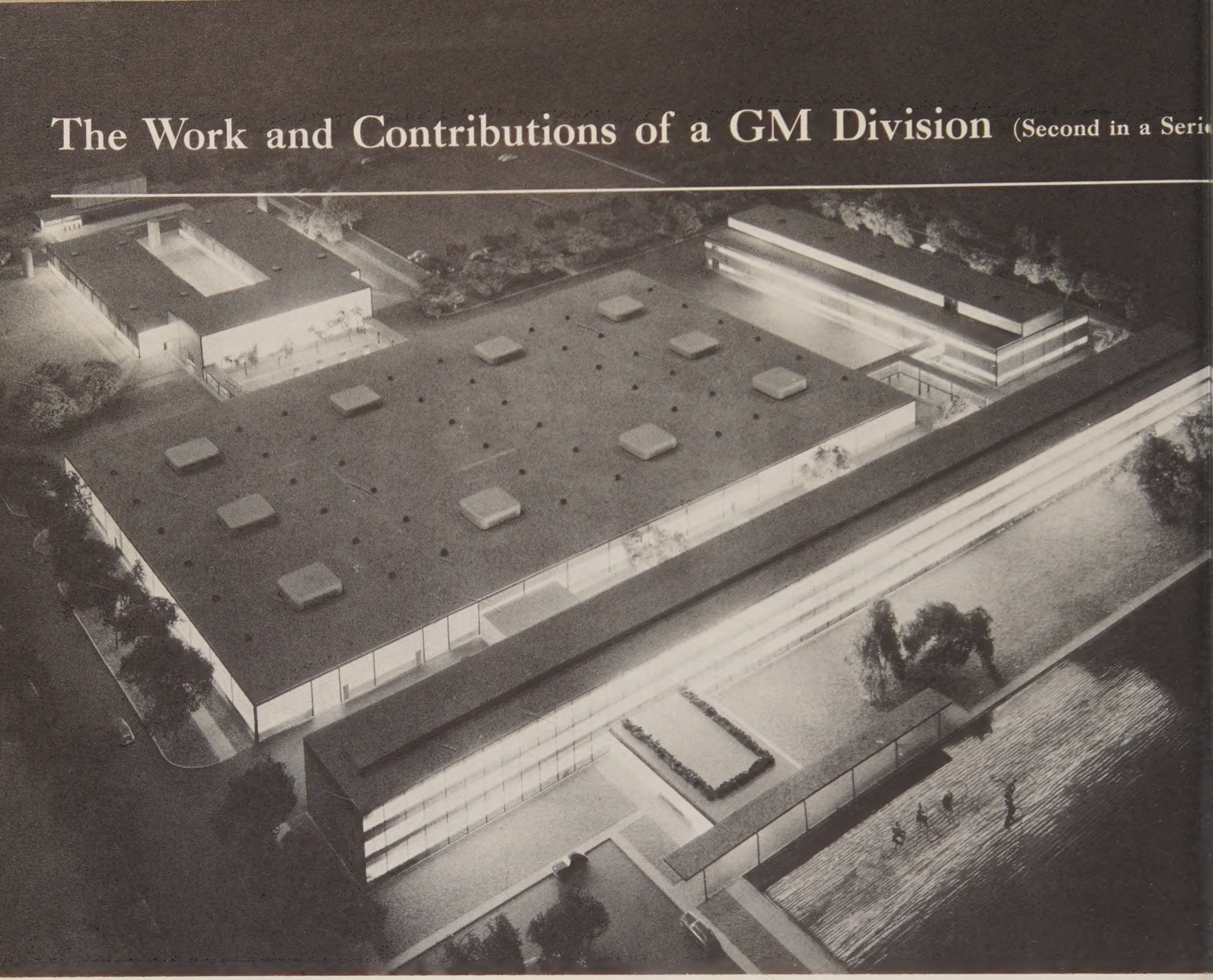


Fig. 1—Fluorescent lighted partial model shows how facilities of the Research Laboratories Division will look at the GM Technical Center, just north of Detroit. Departments now located in Detroit will move to eight new buildings, expected to be completed in 1954. The three-story laboratory building is in the foreground. Behind it will be the process building. Already in use are the metallurgical building shown at the extreme right and the U-shaped mechanical building and separate fuel building at the top.

In an age of competitive business, the need for technological progress mounts swiftly. Few companies engaged primarily in the manufacture of products priced to sell find time and funds for more than project, product, and production engineering tasks—those technical activities which keep the quality up and the price down. Today's effort must be spent on the improvements which the customer expects tomorrow. The Research Laboratories Division was established specifically to take the long look beyond tomorrow to a decade or two ahead. Hence, its projects include such basic research as fundamental studies on magnetism. While looking far ahead, its personnel stand ready daily to assist, in a kind of industrial consultant capacity, with the engineering problems of General Motors operating Divisions everywhere.

INDUSTRIAL research is one of the principal means for the improvement of the national economy. Its developments contribute to the continuous improvement of existing industries and to the creation of new ones. Translating the findings of research into products results in new employment opportunities for labor, greater stability for business, and new or better products for ultimate consumers.

In the past half century, industry has increasingly recognized its responsibility for carrying on basic investigations in pure science without commercial objectives. These basic discoveries, backed by progressive businessmen, became new industries. Today, most companies support research in some form. This union of organized science with industry, only 50 years old, is now accepted and rapidly expanding.

It is natural that the largest and most active research programs are supported by those industries which were themselves created by industrial research. An idea in a man's mind is of small use to the world unless that idea is brought to fruition

By RALPH A. RICHARDSON*
Research Laboratories Division

How basic and applied research lead to product improvements

through engineering research and scientific development—a process that usually requires considerable expenditure of time and funds. Industry finds it good business practice to expend both the time and money to nurture embryo ideas.

Research at General Motors

General Motors early recognized that, to insure continuing technological progress, it would be essential to provide the maximum in quality, comfort, and value to the buyer. This, in turn, indicated the necessity for adequate and organized research. Accordingly, in 1920, The General Motors Research Corporation was established at Moraine City, Ohio. In the summer of 1925, the Research Corporation transferred its laboratories to Detroit to be nearer the larger automotive manufacturing Divisions of General Motors. Later, in 1938, Research was promoted to the status of a Division and the name was changed to Research Laboratories Division, General Motors Corporation. Research will soon move to its eight new buildings at the General Motors Technical Center, located just north of Detroit (Fig. 1). Some activities already have moved.

General Motors is a decentralized organization in which each manufacturing Division has full authority and responsibility for its products. Therefore, each Division holds the responsibility to develop and engineer the products it sells. The Research Laboratories Division carries on only a fraction of the research that is done in the organization. But this Division has the distinction of being the one organization in GM that deals solely with fundamental technical developments. The results of its work are available to any Division which has a need for them.

The Research Laboratories Division is concerned with the future. In general, Research projects are long-range, broad problems not aimed at a specific product except in an emergency when called upon by a Division for consultation or aid in an unusual production problem. Research seeks to insure that GM will keep up with and ahead of advances in the automotive industry.

Research Policies

It is the policy of Research continually to explore the future. Its program aims at a balance between pure and applied science. The total work is divided into (a) fundamental science research, (b) engineering research, and (c) advanced engineering development.

Fundamental science research is usually on the phases of physics, chemistry, mechanics, and metallurgy in which more information is desired. It may or may not lead to definite product applications. It is carried out in the hope that new fundamental information will give a better understanding of the more immediate problems.

Engineering research attacks the fundamental engineering problems encountered in developing new products. Like fundamental science research, it aims at broad basic studies that have wide applications.

Advanced engineering development aims at producing new products and processes to be used by other Divisions. Its objective is the development of working samples to demonstrate new principles.

Organization of Research Division

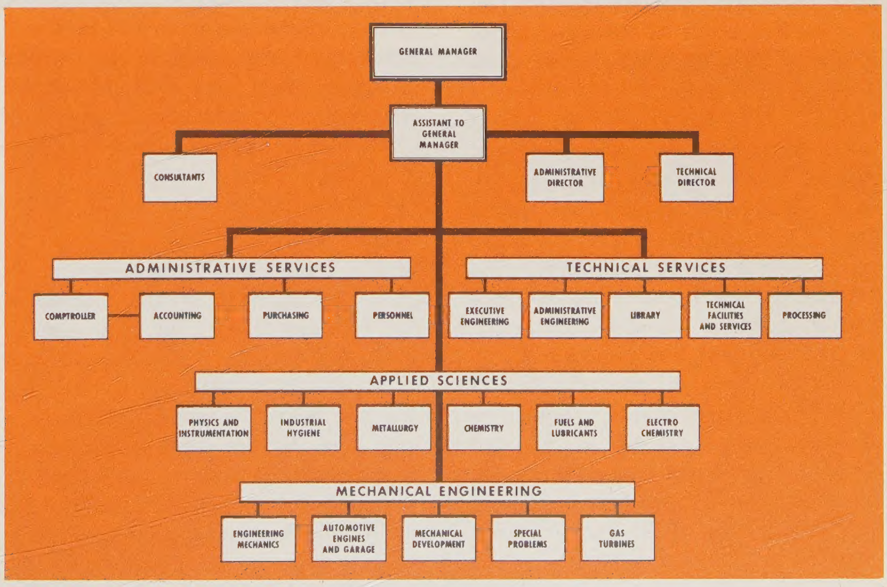
Fig. 2 shows the organization of the Research Laboratories Division. The general manager and assistant to the general manager are concerned with major policy matters in all phases of technical, administrative, and financial operations. The administrative assistant and technical director cooperate with them to shape the basic policies which guide the various Departments.

The Administrative Engineering and Executive Engineering Departments, composed of men with an engineering background, assist the executive staff in administrative problems. These two Departments are part of the Technical Services group. A scientific library, extensive machine shops, and building service make up the remainder of this group.

The technical work is divided between two main groups of Applied Science Departments and Mechanical Engineering Departments. The total personnel of all the Departments, according to a recent count, was about 1,050, including 159 engineers, 29 chemists, 21 physicists, 23 metallurgists, 70 designers and draftsmen, 180 laboratory aides and technicians, and 570 clerical and shop employes.

It is not unusual for several of the Departments to be working on the same project, each contributing its specialized facilities. This team method allows the potential experience of all of the Departments to be focused on the problem.

Fig. 2—Organization of the Research Laboratories Division shows eleven technical Departments each devoted to specific types of problems. Careful coordination prevents duplication of effort and utilizes the special knowledge of all groups.



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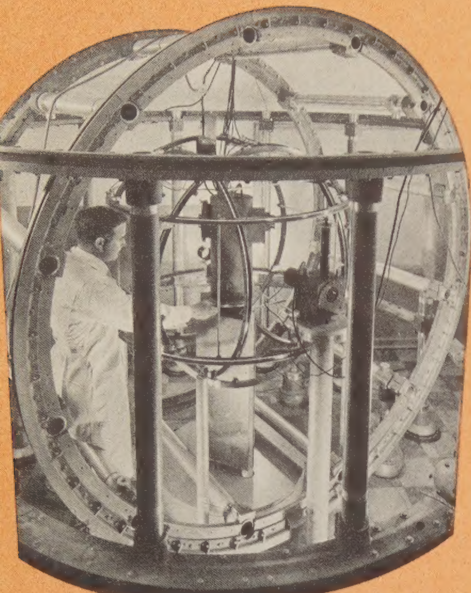
*For photograph and biography, please see p. 65 of June-July 1953 GENERAL MOTORS ENGINEERING JOURNAL. This is Mr. Richardson's second contribution to the JOURNAL.



◀ Fig. 3—The fundamental study of magnetism is one of the basic studies carried out by the Physics and Instrumentation Department. Much of the instrumentation used by Research is developed and maintained by this Department.

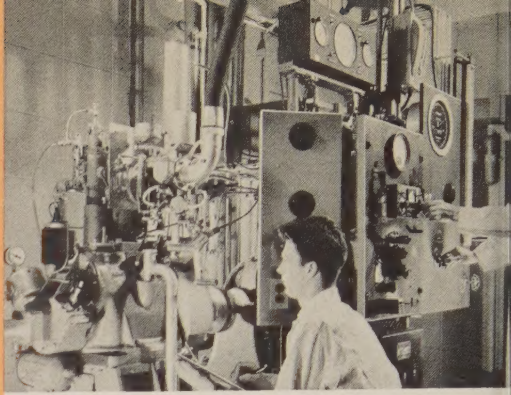


Fig. 4—A new air metering system was designed for single cylinder investigations in the Fuels and Lubricants Department. Accurate measurements of air flow are attained along with precise control of air consumption and air inlet conditions. The air system is isolated from variations in atmospheric conditions, being supplied from a high pressure tank, and consumption is measured by employing the principle of critical or sonic flow through convergent nozzles.

Applied Science Departments

Physics and Instrumentation Department

The work of the Physics and Instrumentation Department covers both applied and theoretical physics. This Department employs physicists, electrical engineers, and some mechanical engineers. They are responsible for a large number of projects in fundamental and applied physics. One of their fundamental projects is a study of magnetism, upon which they have carried on active work for over 15 years (Fig. 3). This work is aimed at advancing knowledge of magnetism, and in time may help answer the physicist's question, "How is force transmitted through space?" This is a good example of fundamental research in which the aim is to add to the knowledge of science.

Much of the work of this Department has a more definite objective, however. Active projects are carried on in spectroscopy, X-ray, ultrasonics, and similar subjects. An infrared spectrograph, designed and built by the Physics and Instrumentation Department, has been used in studies of engine exhaust, paint deterioration, and fuel composition.

Another important part of this work is the development of new instrumentation for projects carried on by other Departments. In the past several years, important contributions have been made in the application of the electron microscope in metallurgical research.

Fuels and Lubricants Department

The assignment of the Fuels and Lubricants Department is to discover more about petroleum base fuels and lubricants (Fig. 4). This group has been studying the fuel problem for over 30 years. Of primary concern is the combustion of fuel as it occurs in the piston-type internal combustion engine and the relationships between the nature of combustion and the environment within the engine.

Chemists study the relation between the molecular structure of fuels and knock. In addition, they study pre-ignition and auto-ignition. One of the services they perform is the blending of special experimental fuels. In addition to the discovery of tetraethyl lead as a knock suppressor, they have made many fine contributions in fundamental studies of combustion and hydro-carbon chemistry.

Metallurgy Department

The Metallurgy Department is the first Department of Research to have its new headquarters at the Technical Center. Since one of the basic jobs in General Motors manufacturing plants is working with metals, it is not surprising that the Research Laboratories have a large, new building devoted exclusively to metallurgical research and development (Fig. 5). In brief, this activity has the problem of developing new alloys and new processes. Studies are made with both ferrous and non-ferrous materials.

Typical of recent accomplishments is a new aluminum dipping process, Aldip, which results in a corrosion resistant coating for steel stampings, forgings, and castings. Not the least of Metallurgy's responsibilities is the cooperative work with the other Departments of Research and the production Divisions.

Chemistry Department

The fuels, lubricants, plating solutions, metal cleaners, polishing compounds, and any chemical material used by the automobile industry, are scrutinized by the Chemistry Department. A large amount of work on improving the durability of automobile finishes and protective lacquers is done. Polarographic, spectrophotometric, spectrographic, and colorimetric analyses are some of the technical procedures used. One of these is illustrated in Fig. 6.

To study the problem of the effects of sunshine, high humidity, and rain on painted or plated parts, the Chemistry Department operates a test field at Coral Gables, Florida. In addition, considerable time is spent in developing new qualitative and quantitative analytical procedures.

Electro-Chemistry Department

The Electro-Chemistry Department combines two separate functions: (a) electroplating and (b) rubber and plastics work. The first is concerned with new developments and problems in electroplating and equipment is available to do special plating research. Fig. 7 shows a typical study.

The rubber and plastics section works on the evaluation and compounding of new rubbers, adhesives, and plastics. The primary concern is with application research, filling the gap between the producers of these materials and the production Divisions which use them.

Industrial Hygiene

The Industrial Hygiene Department is a combination of medical, biological, and engineering groups whose concern is to protect employes from possible sources of occupational illnesses. Major services performed by Industrial Hygiene are consultation on problems of ventilation, atmospheric pollution, safe handling of chemicals, and periodic blood analyses of employes.

When new methods or materials are installed, Industrial Hygiene studies them to determine if employe exposure might result in illness. With special instruments, the Department's researchers can detect minute quantities of gases, dusts, fumes, and mists. Then controls are devised and safety codes set up to prevent the potential health hazard.

Mechanical Departments

The Mechanical Departments are groups composed largely of mechanical engineers, each group specializing in some general line of development work.

Engineering Mechanics Department

Crankshaft fillet rolling to increase fatigue life is a typical project of the Engineering Mechanics Department. This group of mechanical engineers and mathematicians is concerned with fatigue studies and stress analyses of materials and parts. For example, fundamental work on gearing has made gear drives far more durable than they were some time ago. Fundamental studies of residual stress in highly stressed parts have been of great value in giving longer life and greater durability when applied to automotive and aircraft parts. Out of this fundamental work has come shot peening and other mechanical treatments which increase the fatigue life of parts. A comparison of a new and old type of ring gear summarizes the results of this work. In 1930, a conventional 90-hp engine required an 11-inch ring gear. Now a 7-inch ring gear is used with an engine of over 200 hp.

Automotive Engines Department

The Automotive Engines Department centers its activities around the development of more efficient piston-type automotive engines, engaging in research on basic engine design and on specific engine components. Studies of fuel economy, octane requirements, carburetion, and other performance factors are made on dynamometers and by road testing at the GM Proving Ground near Milford, Michigan.

The past work of this Department is largely responsible for present high compression engines in use by GM (Fig. 8). Fundamental engine studies carried on since 1945 alone have made it possible for the production Divisions to increase compression ratios from about 6.5 to 1 to as much as 8.5 to 1—a gain of two ratios.

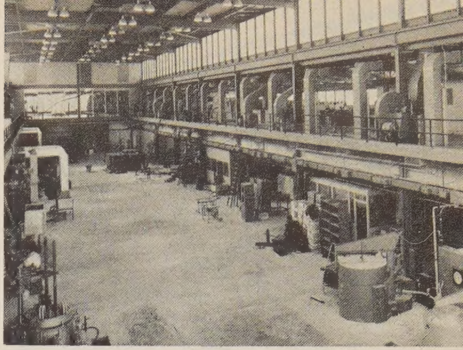


Fig. 5—The new quarters of the Metallurgy Department at the GM Technical Center include a modern foundry with a total melting capacity of almost 3,000 lb per hour. Studies carried on here include corrosion, wear of metals, powdered metals, and service problems.

Mechanical Development Department

This Department is concerned with a variety of projects: unconventional engines, Diesel engines, fatigue testing (Fig. 9), friction, lubricants, and bearings. The Department's Diesel engine project is directed at developing higher power output and improving the reliability of injectors, pistons, connecting rods, and cylinders. Work on a fundamental friction project is concerned primarily with metals sliding on metals to attempt to discover why certain metals are compatible with regard to friction and others are not.

One of the recent developments is a mechanical heart pump successfully used in operations to permit blood to by-pass the heart during the course of an operation.

Special Problems Department

The Special Problems Department is a fourth mechanical engineering group. Part of this Department is concerned with the development and production of Research-designed static and dynamic balancing machines like that shown in Fig. 10. Balancing machines used for the production balancing of rotating parts are built and sold by the Research Laboratories Division. This work acts to support its large and extensive machine shop.

Another part of the Special Problems Department is concerned with vibration and noise problems. Included in this work is an active program on special instruments which has resulted in the development of a strain gauge, torsional vibration indicator, and portable vibration indicator. This Department also has an extensive project on mechanical calculators and operates the data processing machines. It may be that the next generation of engineers will need to know how to use these mechanical brains just as today's engineers have to know how to operate a slide rule.

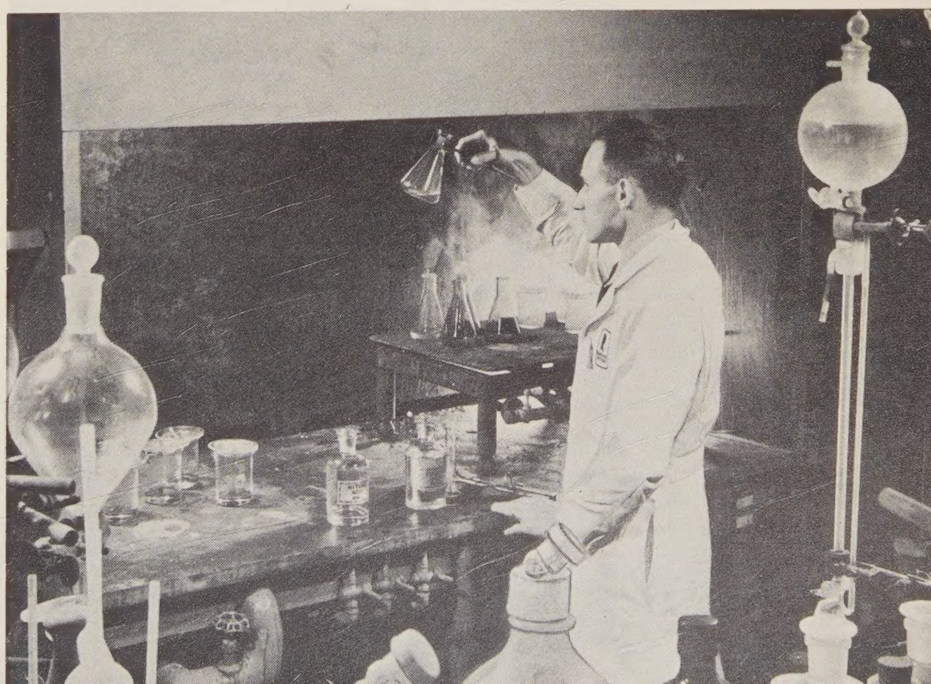


Fig. 6—Preparing samples for spectrophotometric analysis, as shown here, is one of the wide variety of tests and analyses conducted by the Chemistry Department in connection with materials used in manufacturing. New materials which may prove to be substitutes for existing ones also are examined.

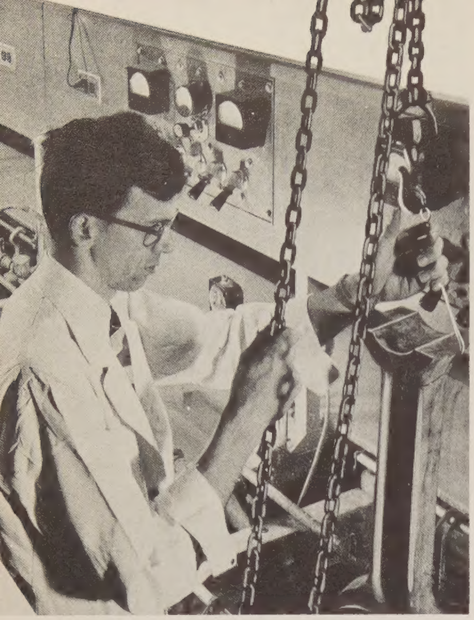


Fig. 7—A Diesel connecting rod receives special electroplating treatment in the Electro-Chemistry Department. Rubber and plastics work is a second principal activity of this Department. New types of synthetic or natural rubbers are sought. Attention also is given to the development and application of adhesives and plastics.

Gas Turbines Department

The main work of this Department is power plant development, with special emphasis on gas turbines. Its activities include theoretical thermodynamic analyses plus actual design and test work. Besides the facilities at the Research Building, the Department maintains a separate test building where special gas turbine problems are investigated.

In addition to turbine research, the Department conducts studies on Diesel injectors and cooperates on other Research problems in which its knowledge of energy cycles is especially valuable.

Technical Services Departments

While the activities under the Technical Services Departments are not directly engaged in research, they are important because of the technical services they perform for other Departments. The responsibilities of technical references, plant improvement, and maintenance, which Technical Services Departments are designed to perform, would not be met by the other Departments without the sacrifice of valuable project time.

Technical Facilities and Services Department

This Department is a specialized, technically adept housekeeping unit in charge of maintenance, service, project facilities, healthful working conditions, and contracts with outside contractors. Recently, the work of the Department has been devoted almost entirely to the planning and construction of the new Research buildings at the Technical Center. It deals with both the construction and layout and the selection and purchasing of specialized equipment.

Processing Department

The Processing Department's facilities include machine shops, pattern shop, grinding room, sheet metal shop, heat treat, and die section, plus the welding, machine and tool design sections. They provide the highly specialized facilities for building the things developed by the Research technical Departments and other units of General Motors. One of the important reasons for the success of Research is the unexcelled facilities for making the new instruments, machinery, and equipment which have always been available. About one-third of Research personnel are employed in the various shops in order to make the Research Laboratories Division independent of outside sources of fabrication.

Library

Scientific and technical books and periodicals are as essential as precise instruments and test equipment. The Research Library, organized about 30 years ago, now houses approximately 35,000 pieces of technical literature and is still expanding. Its periodical subscription list totals 347. In performing its function within General Motors, the Library sends materials throughout the free world. One service is the distribution of research reports throughout the Corporation as permanent copies to interested personnel.

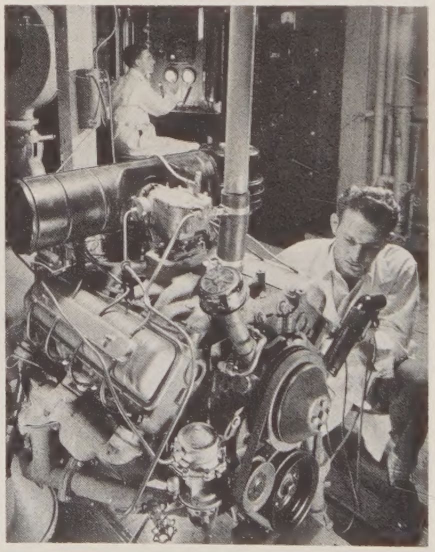


Fig. 8—The Automotive Engines Department conducts research on basic engine design and on specific engine components. Complete engines for research study can be constructed with the shop facilities of the Division's own Processing Department. This engine may be altered to operate at 8, 10, or 12 to 1 compression ratios in high-octane fuel studies.

Personnel Department

The objective of the Personnel Department, one of the Administrative Services group, is to provide Research with quality manpower. It recruits college graduates and technical personnel for the laboratories and oversees employe and labor relations. In addition, it manages programs for college graduates in training, cooperative students, apprentices, and summer students. The enlarging of the self-improvement program for Research engineers is the Personnel Department's newest project.

Research Accomplishments

Since its origin 33 years ago, the Research Laboratories Division has worked on thousands of projects aiming at the development of new products and the improvement of old ones. The successful ones are used on every General Motors product. The unsuccessful ones have prevented the Divisions from making mistakes in the production of their products.

The advancements in which the Research Laboratories Division has participated are too numerous to list herein. Typical and significant are the following: the development of Ethyl gasoline, which permitted the evolution of high compression engines with greater efficiency and power; the Diesel engine development, resulting in a new type two-cycle engine that brought efficient, low-cost Diesel power to the railroads and ships; gear studies, contributing to better rear axles and transmissions; harmonic balancers, making engines run more smoothly; chromium plating for protection of decorative metal parts. Still other developments are domestic mechanical refrigeration, lacquer finishes, static and dynamic balancing machines, bright copper plating, safety glass, quantitative spectrographic analysis, Triptane process, copper-lead bearings, instantaneous silver plating process, and tellurium-treated malleable iron. These are aside from the extensive long-range studies in magne-

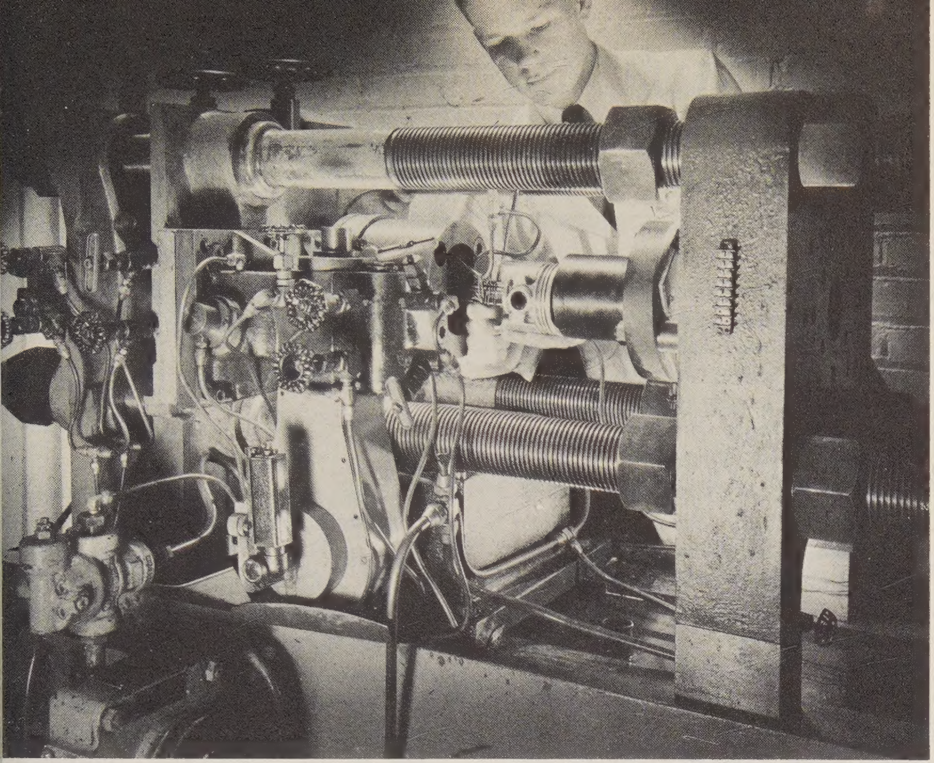


Fig. 9—This hydraulic fatigue testing machine, built by the Division, provides information on automotive engine components for investigations carried on in the Mechanical Development Department. Tests also are made on bearings, lubricants, surface finishes, Diesel engines, and automobile cooling.

tism, combustion, bearings, friction, and brakes. Recent developments have been Aldip, an aluminum dipping process; new high temperature alloy materials for gas turbines; surface finish gauge; bright copper plating; high compression engines, and new types of balancing machines.

Technical Center

The Research Laboratories Division is making plans to complete its move to the General Motors Technical Center, its fourth home since 1920. Begun in 1949, the Technical Center buildings assigned to Research are expected to be completed during 1954. As Research moves to the Technical Center, it will acquire some of the finest facilities of their kind in the world—in keeping with the expanding importance of science and engineering in modern industry.

The metallurgical building, already in use, houses new and expanded facilities including electric and gas furnaces, molding and pouring equipment, metallurgical laboratories, high temperature alloy creep test cells, salt spray cabinet, humidity room, pattern shop, and office. The new foundry, now in operation, permits the Metallurgy Department to expand the variety and quantity of castings produced for service and development work.

The mechanical building, now being occupied, contains the engine dynamometer rooms, fatigue test machines, bearing test machines, and other mechanical engineering equipment. A separate fuel blending building supplies the many kinds of gasoline and fuel oil needed in the dynamometer rooms.

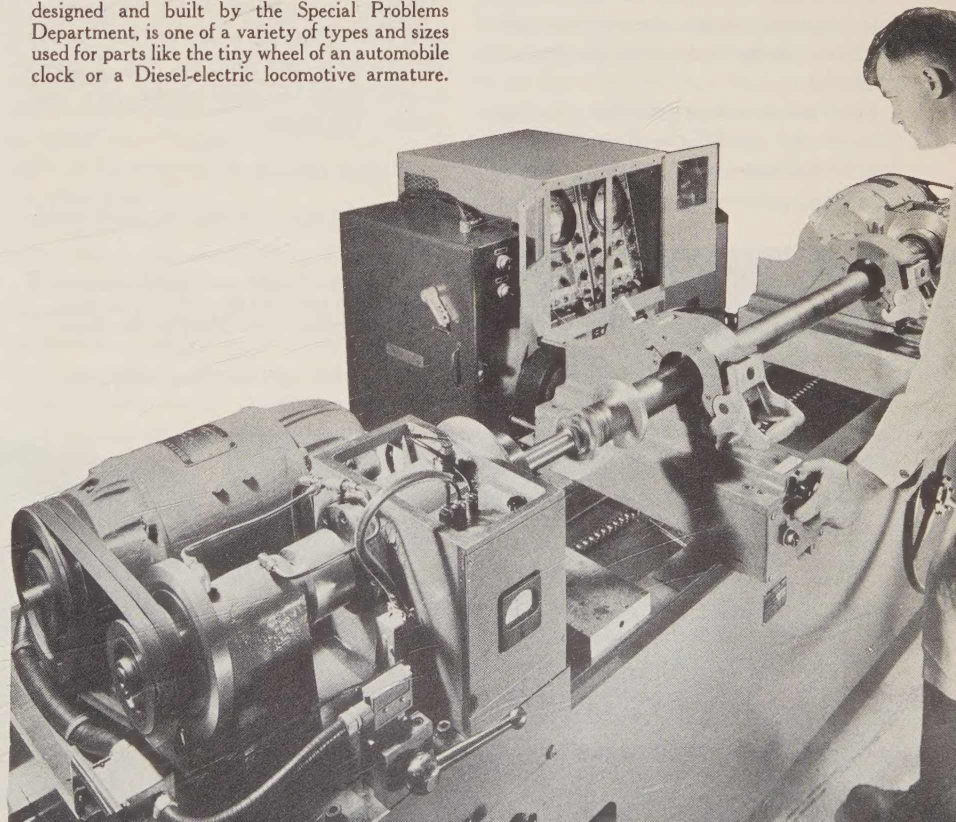
Separated from the main group will be a special building for gas turbine research. It will contain test cells for both large and small turbines.

A process building will house the machine shops, heat treat shops, electroplating facilities, cold rooms, and garage.

The long, three-story laboratory building will contain the various chemical, industrial hygiene, electrical, and physics laboratories plus the executive offices, drafting rooms, and library.

A large automotive wind tunnel and a radioactive isotope laboratory will complete the present program of eight new Research buildings.

Fig. 10—A propeller shaft balancing machine, designed and built by the Special Problems Department, is one of a variety of types and sizes used for parts like the tiny wheel of an automobile clock or a Diesel-electric locomotive armature.



Summary

Most of today's new products—artificial silk, anti-knock gasoline, synthetic rubber, and light-weight alloys—come from industrial research laboratories backed by enlightened business management. Research gives more new knowledge every year than this generation's grandfathers had in a lifetime. It is possible to depend on something in addition to the nation's natural resources of farm, mine, and forest. Organized research supported by industry has already given much—and offers more for the future.

Making Castings by Shell Mold and Investment Processes

By ROBERT R. DOHRMANN
Fabricast
Division

How modern methods yield parts of good dimensional accuracy

A completed part must be true to print, and conventional sand molding methods followed by machining and other finishing operations yield required accuracies. However, the closer tolerances are held in the foundry, the less subsequent work is required, and considerable attention is devoted today to methods for holding castings to closer tolerances. The shell process, based on certain German patents which have been released to industry, is one rather recent method and another is investment molding, which has grown from the *lost wax process. Both methods have advantages and limitations which must be understood before their application to production of castings.**

Two methods available to precision casting foundries are shell molding and investment molding. The former is of more recent vintage, originating in the year of 1945 when certain German patents were investigated by the Allied Powers and released to industry. Investment molding is a refinement of the *lost wax* process which, in the past decade, has been adapted to the production of close tolerance, high finish parts cast from the heat resistant alloys used in the jet engine.

Neither of the two methods produces a precision product by present day machining standards, but the castings produced are precise when compared to products of conventional sand molding.

Shell Mold Casting

(For a comment by J. H. Smith, general manager of the Central Foundry Division, on the shell mold process, see page 11.)

Shell mold casting provides a bridge between the possibilities of sand casting and investment casting, and is presently being used for producing castings up to about 25 lb in weight. Fig. 1 shows some typical Fabricast products cast from shell molds.

The process involves a relatively expensive molding material. The greater expense can be offset by low-weight shells, increased casting accuracy reducing machining costs, superior surface finish, and the ability to form small, intricate cored sections that would be difficult or impossible in conventional sand molding. Dimensional accuracy stems from the fact that the shell is formed *and cured* on an accurate metal pattern.

A shell mold or core is produced from sand mixed with a thermosetting phenolic resin binder which is dumped or blown against a hot metal pattern or core box. The shell is cured while on the pattern, and after stripping is immediately ready for assembly and pouring. Fig. 2 shows a representative shell mold core and pattern equipment.

Shell Mold Material

The selection of a sand for shell molding is based upon various factors, principally: finish required, mold strength, and permeability. These requirements vary with different metals and casting types. Coarse sands require less binder to provide adequate strength, but result in a rougher casting surface. A silica float sand of 115 *AFS* fineness has been found to be a good general purpose sand.

Most of the commercially available shell mold powdered phenolic resins are comparable in quality and cost. The resin content is maintained at six to eight per cent of the sand weight; however, preliminary work on resin-coated sand indicates that resin contents as low as three and one-half per cent are feasible. Resin cost is the major price factor in shell molding, and the resin content is, therefore, held at a minimum.

Refractory additives such as iron oxide, aluminum oxide, and silica flour, are occasionally added where finish, mold reaction, or metal penetration are casting problems.

Mixing of the media is accomplished in conventional mulling equipment with the addition of a wetting agent or light oil to suppress dust and improve resin distribution.

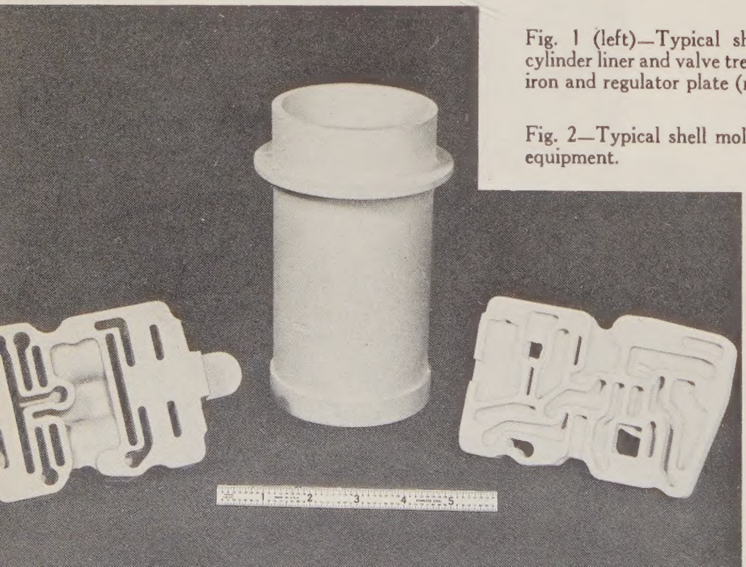


Fig. 1 (left)—Typical shell mold castings: cylinder liner and valve tree (left) of alloy grey iron and regulator plate (right) of aluminum.

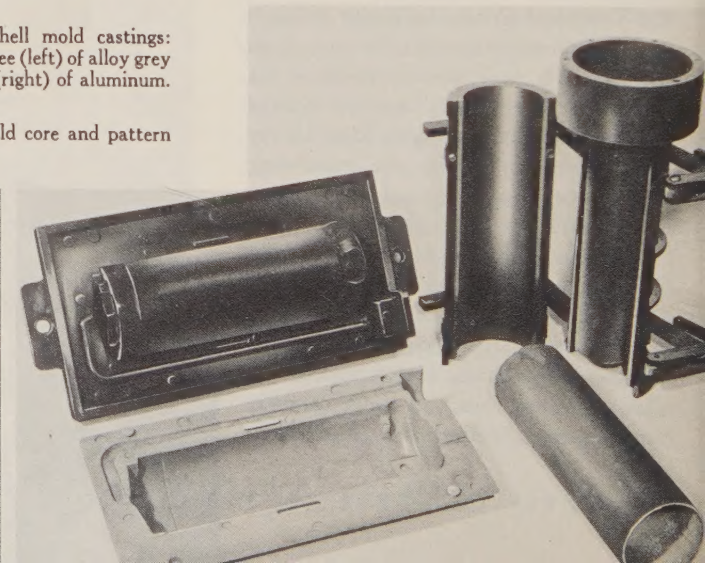


Fig. 2—Typical shell mold core and pattern equipment.

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*Glossary on p. 12.

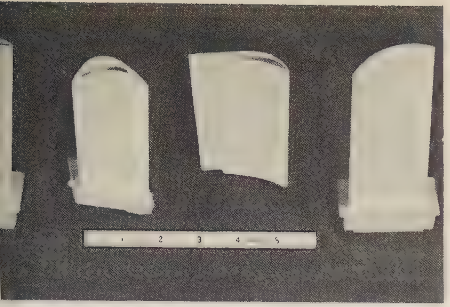

Fig. 3—Investment cast gas turbine components.

Shell Mold or Core Production

Patterns are usually made of grey iron, and occasionally aluminum. Accuracy is paramount in the shell pattern equipment, which must incorporate metal shrinkage, shell mold shrinkage, and one-half to one degree pattern draft.

Blowing of shells is accomplished with a specially designed blowing apparatus. The heated pattern (350-400° F.) is placed under a blow-head, which is a female of the pattern containing blow tubes and vents; the shell is blown, and the pattern and green shell removed to a curing oven (600-800° F.). Curing is effected in one and one-half to two minutes at 800° F. Curing temperatures above 800° F. invariably result in objectionable shell warpage.

The cured shell is parted from the pattern by ejector pins incorporated in the pattern. The pattern is blown clean with air and sprayed with a parting compound preparatory to producing the next shell. Blowing of shells has the advantages of accurately filling intricate pattern sections, forming a uniform shell thickness enabling the use of form fitting backing frames, and eliminating the pattern rollover necessary to the dump process. Disadvantages of blowing are resin segregation and unavailability of commercial equipment for automatic operation.

The *dump* process uses a molding box, mounted on trunnions, containing the molding media. The heated pattern is placed face down on the box, the box inverted for 15 to 30 seconds to allow the desired shell buildup, the box re-inverted, and the pattern and green shell removed to a curing oven. Commercially available dump machines produce shells by molding, curing, and stripping automatically at a rate of 40 to 60 per hour. The dump process has the disadvantage of being unable to produce sound shells in intricate casting sections, but is advantageous on account of the availability of commercial equipment and simplicity for tooling for small job lots.

Mold Assembly and Pouring

This phase of operation most critically affects the dimensional quality of shell castings. Gluing, stapling, taping, or clamping, followed by imbedding the shell in sand or shot, have proven to be unsatisfactory where dimensional accuracy is of prime importance. Tape and glue tend to hold the parting line of the shells apart in mold assembly and, with the sand or shot backing, lack sufficient strength to withstand the heat and hydrostatic pressures of the molten metal. Hence, Fabricast Division has designed and uses for most purposes a permanent backing apparatus employing metallic frames which are contoured to the backside of blown shells. On grey iron castings, a backing of this type results in dimensional accuracy of about ±0.003 in. per in. on areas contained in one shell and ±0.007 in. per in. across the shell parting.

Another method, applicable to small job lots and experimental runs, is to back the shells with dried sand and clamp or wedge the backed shells together.

Casting Shakeout and Cleaning

The high metal temperatures in pouring ferrous alloys reduce shell mold shakeout to a minimum as the resin binder burns out and converts the shell to a mere layer of sand. However, in non-ferrous alloys, the removal of complicated shell mold or core sections can be complicated by the fact that the lower metal temperatures do not break down the resin bond.

Only a minor amount of sandblasting is required to clean castings after shakeout.

Shell molding is inherently expensive, as the high cost of powdered resin binders renders the molding media four to five times as costly as dry sand. The cost of the shell mold mix per pound is over five times the cost of a pound of the oil sand mix.

Investment Casting

The investment process is usually applied to castings of small size (one pound or less) and utilizes expensive materials and processing. It produces castings of excellent surface finish, and its dimensional accuracy stems from the use of an accurate expendable pattern, plus the use of a one-piece mold free from parting lines. However, minor surface imperfections invariably occur which must be removed by polishing or machining, and render the production of precision *as cast* threads or working surfaces quite difficult.

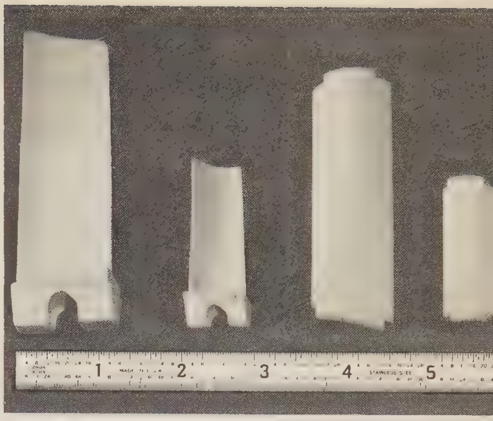

Fig. 4—Investment cast multistage turbine vanes and blades.

This discussion concerns the production of turbine buckets, blades, and vanes for gas turbines cast in heat resistant alloys, which are generally regarded as neither forgeable nor machineable. Tolerances required on ¼ in. thick airfoil sections are ±0.0075 in. with a true overall spread on castings more closely approximating ±0.010 in. Typical investment castings produced at the Fabricast Division are shown in Figs. 3 and 4.

Pattern Production

An accurate expendable pattern of wax or plastic is formed in precision dies on an injection machine. Soft metal dies are usually used for short-run wax injection, while steel is used on long term runs and is required for plastic injection. These dies are extremely expensive due to the precision required.

Polystyrene plastic patterns are preferred to wax, as they are more dimensionally stable, easier to handle, and easier to produce due to the availability of high quality injection molding machines. Many types of injection waxes are available at about two and one-half times the cost of polystyrene. Both types of material are discarded after pattern burnout, as this operation adversely affects their physical and chemical properties.

Runners, risers, and other elements are also of wax or plastic and are joined to make a pattern assembly by *wax soldering* or adhesives.

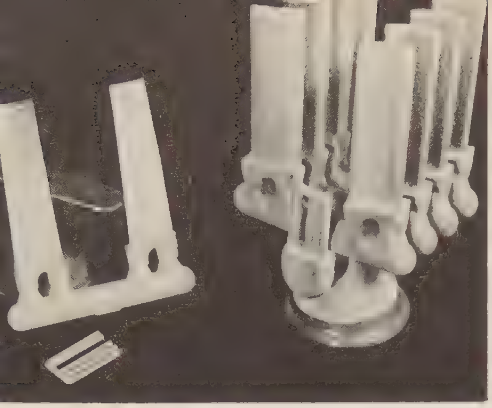

Fig. 5—Typical pattern components (left) and pre-coated pattern assembly.

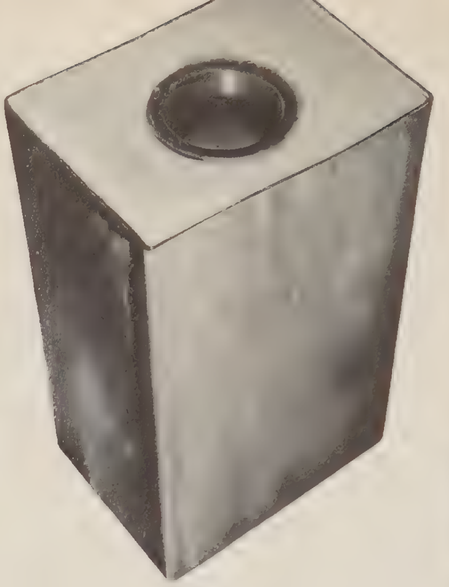

Fig. 6—Typical investment mold.

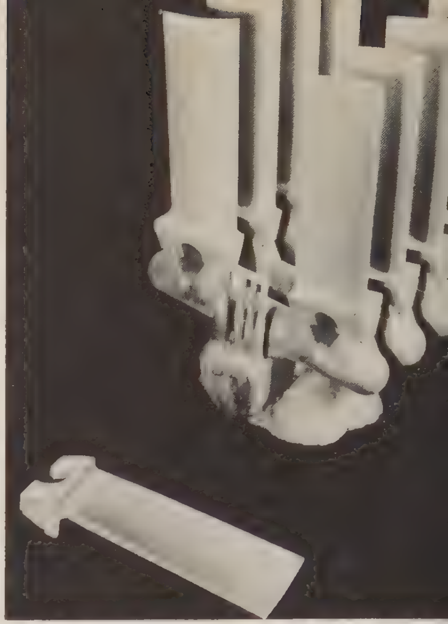

Fig. 7—Sandblasted casting tree with finished casting in foreground.

Pattern production is one of the most critical phases of investment casting as the castings can be no better than the patterns, and in general, pattern defects are magnified by casting variables.

Dip Coating Patterns

A two-step investment, utilizing a thin pre-coat backed by a coarse secondary investment, is preferred in casting high temperature alloys.

The pre-coat material is a formulated slurry of silica flour with a sodium silicate binder. The binder also contains an additive for providing green strength, octyl alcohol for defoaming, a wetting agent, and has a water base. The formulation and viscosity of the material are maintained under rigid laboratory controls, as this media is critical in that it forms the casting surface. It must have expansion properties compatible with the secondary backing, form a smooth mold surface free from voids or cracks, and remain stable throughout the remainder of processing. The pattern assembly is coated by carefully dipping it into the slurry in a manner suitable for producing a uniform coating free from entrapped air.

The coated assembly subsequently is air dried under controlled conditions, as excessive temperature variations or too rapid drying causes the coating to crack or part from the pattern and result in poor casting quality.

Pattern Investment

The dried, coated pattern is attached to a metal plate by molten wax. A heat-resistant flask is placed around the pattern and sealed to the plate to hold all units in place for the investing operation.

The investment media is a refractory mixture of dead burned fire clay, silica flour, and minor percentages of an accelerator and a strengthening additive. These materials are first dry blended and then mixed with a hydrolyzed ethyl silicate-alcohol binder to produce an investment slurry. The cost of the slurry used in this process is moderate. An average mold requires about 15 to 20 lb of this material.

The flasks are filled with the slurry and placed on a vibrating table for about one-half hour to vibrate out included air, force out excess liquid binder, and firmly pack the investment about the pattern. The molds are allowed to set for about one hour after vibration, at which time gelation of the binder has occurred. The plates are then broken loose from the mold, and the mold is then oven dried.

Mold Burnout and Preheat

Molds are burned out and preheated in a gas-fired pusher furnace. The entrance end of the furnace is kept at 600-900° F., while the exit end is 1,600-1,900° F. Specific temperatures within these ranges are determined by the casting and type of metal being poured. The time cycle is six to eight hours, and a minimum time and temperature must be observed to prevent cracking of the molds and to insure removal of all organic pattern material.

Melting and Pouring

Heat resisting alloys such as used in turbine buckets of gas turbines require melting and pouring under an atmosphere with absolute temperature control. Melting is done in induction furnaces, and pouring effected by clamping the mold over the furnace crucible and inverting the furnace.

Molds are cooled prior to shakeout, whence they are sandblasted and routed to cleaning and inspection operations.

Casting Cleaning and Inspection

Casting gates and runners are removed by abrasive cut-off wheels, and finish blending and polishing accomplished on belt sanders. By no means are casting finishes obtained in the cleaning room, as surfaces merely require removal of occasional projections and defects. Defects in critical areas cause rejection of aircraft quality castings even though cleaning can be accomplished.

Inspection specifications require rigid acceptance standards. Each casting must pass X-ray, Zyglo, acid etch, dimensional, and visual inspection, and also must be identified as to master heat number.

Figs. 5, 6, and 7 show a typical pattern assembly, dipped pattern, investment mold, and resultant castings.

Conclusion

To summarize, both the shell mold and investment processes have much to offer to foundry practice.

Shell molding is a novel process capable of overcoming some limitations of conventional sand molding methods, and it introduces new casting possibilities. However, it requires careful evaluation by foundrymen prior to application for production.

The investment process is the most precise of existing foundry techniques and requires expensive materials, special equipment, and stringent controls. While constant development is aimed toward simplification of operation and reduction of costs, no drastic improvements can be foreseen in the near future.

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A Comment

Foundrymen are well aware of the potentialities of the shell mold process. To the engineer it can be described as a method of producing castings with a finer finish and to much closer tolerances than can be produced by the present green sand or dry sand molding method.

We at Central Foundry Division consider the shell mold process to be among the most important of our time in the foundry industry. Recent developments and future improvements may revolutionize foundry molding techniques to the point where it will be more economical to produce most small castings, and some large castings, by the shell mold process as compared with conventional, green sand molding.

Two important advantages of the shell mold process are the drastic reduction in the molding material handled—the sand requirement for a shell casting is approximately one-eighth of that required for the green sand method—and the adaptability of the molding operation to complete mechanization.

The cost of the phenolic resins used to provide the bond material for the silica grains in the construction of the shell is the main reason for the process not being more widely used. There seems to be little chance of a reduction of the present high cost of phenolic resin because of the stable price of phenol. Manufacturers are striving to discover suitable resin substitutes and resin extenders. The Research Laboratories Division has a continuous program to try to find a substitute for phenolic resin or a material which can be blended with phenolic resin to produce a less expensive mix. Even at the present high resin cost, many castings can be produced at a cost comparable to green sand molding. This is particularly true where cores can be eliminated by the use of the process.

Many of us who have spent our entire working life in the foundry industry visualize the great possibilities in the shell mold process and are looking forward to the development of many new and profitable applications of this process.

J. H. Smith
General Manager
Central Foundry Division

Glossary

For paper beginning on page 8: "Making Castings by Shell Mold and Investment Processes."

Acid etch inspection is the treatment of a metal surface by an acid for purposes of metallographic analysis or detection of flaws.

Blowing (core or shell) is a process of forcing a molding material, by use of air, into a pattern cavity.

Curing is a process of hardening a mold to a useable degree of strength.

Flask is the term for a metal or wood box without top or fixed bottom containing sand which is rammed around a pattern. Usually consisting of two parts, the lower part called the *drag* and the upper part called the *cope*, the flask remains on the mold during pouring. In investment casting, the flask is a one-piece unit.

Gate is the term for the main channel cut or molded for the purpose of conducting molten metal from the runner into the mold cavity.

Injection machine is the term for a molding machine in which the material is fed by gravity to a circular heating chamber to be compressed, softened, and, under considerable pressure, injected into the closed mold. The finished product, hardened in the mold by cool water circulated through conduits in the mold, is ejected as the injection plunger retracts and opens the mold.

Lost wax process is the name of an industrial application of centrifugal casting using plaster of paris molds and used by the jewelry industry for many years. In this method, vulcanized rubber, stripped from the model, is used as a mold for pouring wax patterns. A number of these patterns are set into a flask which is filled with plaster of paris and allowed to harden. The flask is inverted and steam or hot air is blown into the mold causing the wax pattern to melt and run out of the mold cavity. The plaster mold, placed on a whirling arm, is fed molten metal from a small furnace holding just enough metal for one mold.

Parting line is the line on the casting along which a pattern is divided for molding or the line at which the two halves of mold meet.

Pattern draft is the term applied to the taper on all vertical pattern surfaces which allows the pattern to be removed from the sand without excessive rapping and injury to the mold.

A **pusher furnace** is one of two types where (1) the parts are pushed against each other as in the continuous reheating furnace, and (2) the parts are loaded in trays which are pushed through the furnace.

Riser, or feeder head, is the term for a well of molten metal placed above the heavy sections of a casting to compensate for the contraction of the casting as it solidifies. Risers remain liquid longer than the casting and, as the casting solidifies, feed into the mold cavity by force of gravity.

Runners are channels in the mold used for quick transfer of molten metal.

Shakeout is the rapping or vibrating of a poured mold to successfully remove the casting from the molding media.

Slurry is a mixture of silica flour and a sodium silicate binder used in casting processes.

X-ray inspection is a method of testing and analyzing materials and castings by X-ray photography.

Zyglo inspection is a testing method used for non-magnetic metals. This method uses fluorescent powder and black light to locate cracks in the metal.

A MESSAGE TO ENGINEERING EDUCATORS

about the

GENERAL MOTORS Engineering JOURNAL

THE experimental issue of the *General Motors Engineering Journal* was published in July. The gratitude of the Advisory Board and Editorial Staff goes to those many who have offered their comments on how this periodical might most effectively convey technical information from our laboratories and plants to engineering classrooms.

If you have not requested, directly or indirectly, to be placed on our regular mailing list you are invited to do so by writing to the editor on your institution's letterhead.

While we intend the periodical specifically for the field of engineering education, we would find it extremely difficult and costly to maintain accurate mailing information on students because they change addresses so often. We have therefore established the policy of distributing to students only through engineering educators who might see fit to use the periodical in some way in connection with classroom work. Let us know if you wish to receive copies for this purpose. Requests for bulk quantities also may be directed to the editor.

General Motors engineers are anxious to present technical information which is of value to engineering education and want to present it in a way that is most useable. Your comments on specific papers or on the periodical generally are much appreciated and each letter is given serious consideration.

Kenneth A Meade

KENNETH A. MEADE,
Secretary, Adivsory Board

Use of Foam Plaster Process for Making Aluminum Alloy Torque Converter Castings

By KENNETH B. BLY
Fabricast Division

Fabricating economy without sacrifice of quality is demonstrated in the method employed by Fabricast Division in producing accurate aluminum alloy castings for manufacture of the converter end of the Buick automatic transmission. Cores are made by the new foam plaster process, which is less complicated than the two other plaster processes and provides a wider range of core permeability simply by altering the foam volume. Tensile strength of the resulting castings approaches that of those produced in sand or metal molds.

Kitchen ease in foundry:
"Blend 2 cups foam, 2 cups slurry; set in core box; oven dry below 400°F."

PLASTER is used in the foundry for molds and cores because of its ability to reproduce accurately in non-ferrous castings the dimensional accuracy and surface smoothness of the patterns used. Plaster-molded aluminum castings are surpassed in these characteristics only by pressure die castings. They are suited to those applications where pressure die castings cannot be used because of intricate coring, casting size, and the economics of production quantities. Lower casting costs and smooth internal cored passages can be achieved by using some types of plaster cores in gravity permanent molds.

Plaster is received by the foundry for use as calcium sulphate in the hemihydrate form, or containing half a molecule of water to one of the compound forming the hydrate. When the calcium sulphate s combined with proper amount of water, it converts to a dihydrate, a compound containing two molecules of water, which causes the mass to harden or set. The equation for the reaction is as follows:

$$(CaSO_4)_2 \cdot H_2O + 3H_2O \rightleftarrows 2(CaSO_4 \cdot 2H_2O)$$

The set time, which is important from a production standpoint, is accelerated by mall amounts of Terra Alba (ground gypsum rock) or potassium sulphate. Low water-to-plaster ratio accelerates as well as does high water temperature.

Plaster expands while setting, and it is desirable to minimize the set expansion. This is controlled by high water-plaster ratios or additives such as Portland cement and potassium sulphate. Filler materials can be used, such as sand, talc, or ceramic fibers, which contribute to he green strength, thermal conductivity, and surface finish of cores and molds.

After plaster molds are set, they are removed from their core boxes and are dried to remove water. To minimize steam in the plaster cores and prevent eruption of steam through the molten metal entering the mold cavity, all of the free water and nearly all of the combined water are removed in most plaster casting processes. It is necessary that cores be permeable to allow escape of gases through the core to the outside atmosphere.

The only difference between the three processes used in this country for making plaster cores and molds is the method of achieving permeability. The first of these processes is called *Capaco*[1], and utilizes an excess amount of water to form inter-connecting voids. A high temperature drying of the molds at 1,500° F. results in a limited amount of permeability. The next process, the *Bean*[2] process, makes use of a steam-pressurized autoclave to perform a crystalline structure change in the plaster molds. (An autoclave is an apparatus in which liquids can be heated to above their normal boiling points without complete vaporization.) This process causes the calcium sulphate crystals to readjust themselves to the existing situation and collect into small groups to form balls with voids between the crystalline clusters. Fig. 1 shows the typical structure found in the *Bean* process cores. The cores are dried at temperatures of 350-450° F. with permeability ranging to 40 *AFS* (American Foundrymen's Society) units.

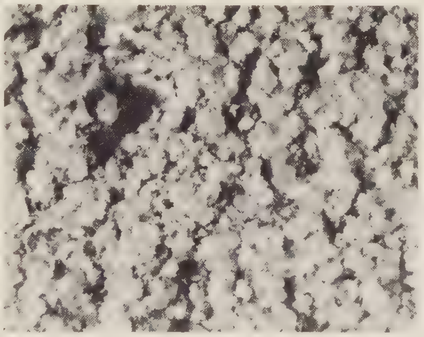

Fig. 1—Bean process plaster core (X10). Enlarged photograph shows the internal structure of the core with clusters of calcium sulphate crystals, sand grains, and the inter-connecting channels between the crystal groups.

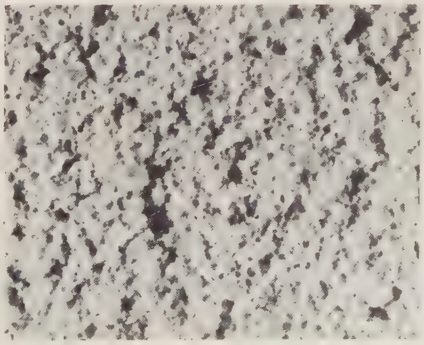

Fig. 2—Foam plaster process core (X10). Enlarged photograph shows the network of the plaster skeleton structure with the inter-connecting foam cells.

The foam plaster process, which has recently been employed at Fabricast Division, Bedford, Indiana, differs from the previous methods in that the permeability or inter-connecting voids are introduced during the wet mixing of the plaster slurry, or thin, watery paste. The process is being used to make the vane passage cores for the torque converter elements for the Buick Dynaflow transmission. These cores are being used in conjunction with gravity permanent molds.

Permeability in the foam plaster process is the result of a maze of inter-connecting air cells produced in the set plaster mold by introducing a surface active agent into the plaster-water slurry to form a foam cell structure which is uniform and small in size. The foam introduced should have a surface tension such that the cell walls break during the setting of the plaster. Fig. 2 shows the typical cell structure of a foam plaster core.

Experience has shown that higher permeabilities, better fluidity, and higher tensile strength cores can be made if the foam cells are pre-generated to a predetermined volume, and then blended with a plaster slurry.

The permeability of the vane cores made from this plaster mix is expected to fall in the range of 40-80 *AFS* units. This can be varied by controlling the amount of foam produced for the mix.

The production operations for making foam plaster vanes for Buick vane cores start with the making of the dry mix of the plaster material with silica sand in one-thousand-pound batches. The dry mix is fed overhead to a hopper above the plaster mixing machine. The plaster mixing machine, called the *Plastermat*, consists of an indexing table with brackets for mounting the 24 cups, as shown in Fig. 3.

Clockwise on the machine table, all odd cups are slurry cups and even cups are foam cups. It is only necessary for the operator, as shown in Fig. 3, to pour the contents of the two slurry cups into two foam cups for blending. Two cups of final mix are received from the machine every 30 seconds. The final mix is transferred to a pouring cup and the plaster mix is then poured into the cavity of a phenolic resin vane core box, as shown in Fig. 4. The core boxes are mounted on a continuous table conveyor.

When the plaster is partially set, the excess is scraped from the top of the core

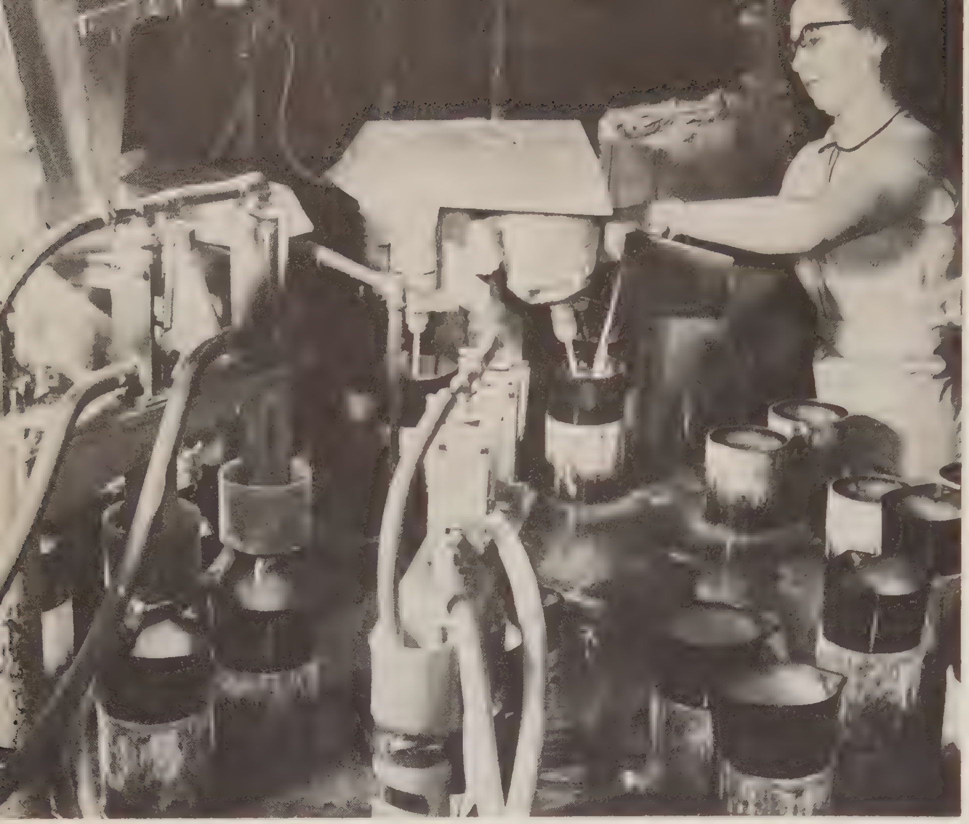

Fig. 3 (above)—View of *Plastermat*, foam plaster mixing machine. Operator is pouring plaster slurry into foam at blending station.

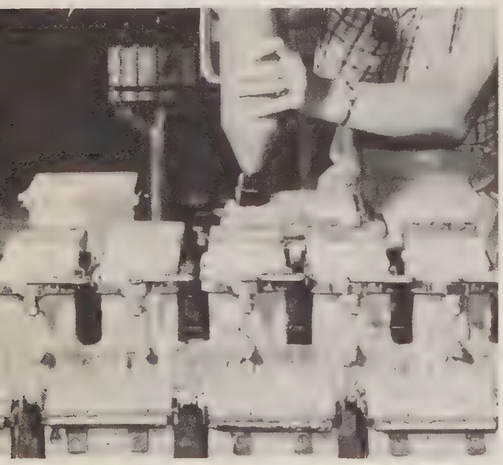

Fig. 4 (left)—Plaster pouring. Operator is filling vane core box with foam plaster.

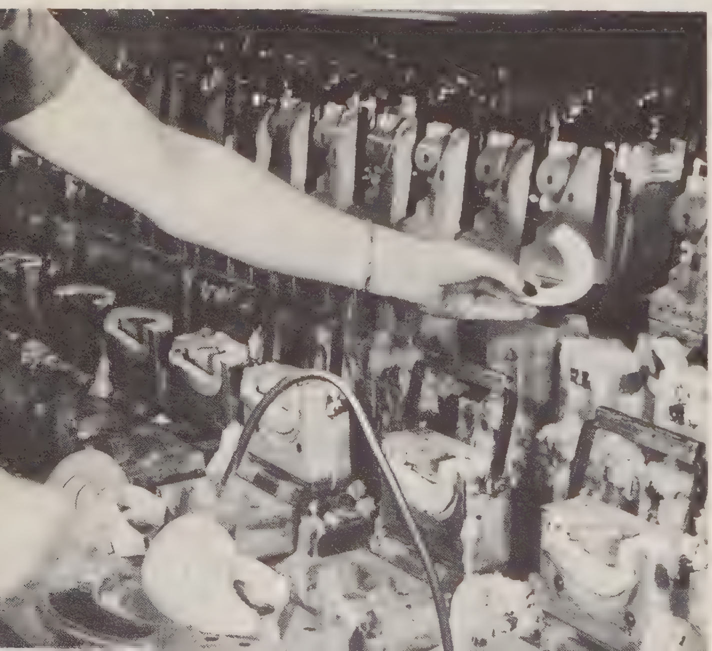

Fig. 5 (below, left)—Core removal. Foam plaster cores being removed from core box, cleaned, and placed on drying tray.

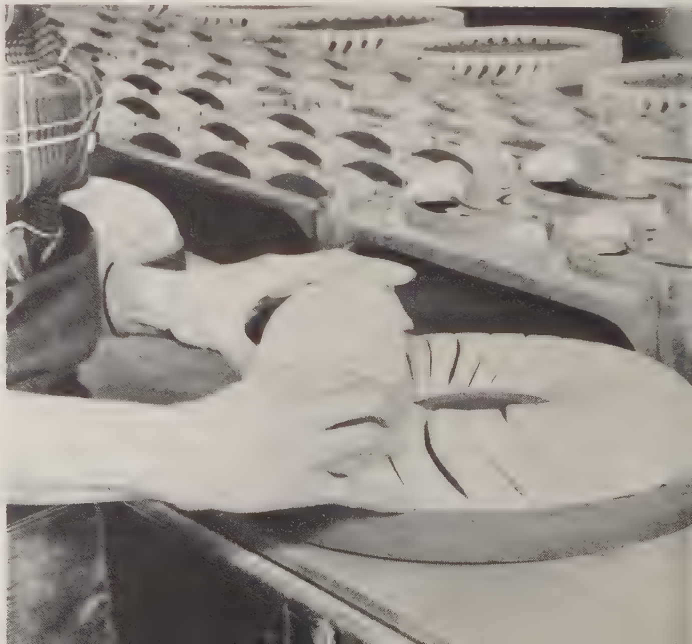

Fig. 6 (below, right)—Core assembly. Dried foam plaster cores being assembled into drag core.

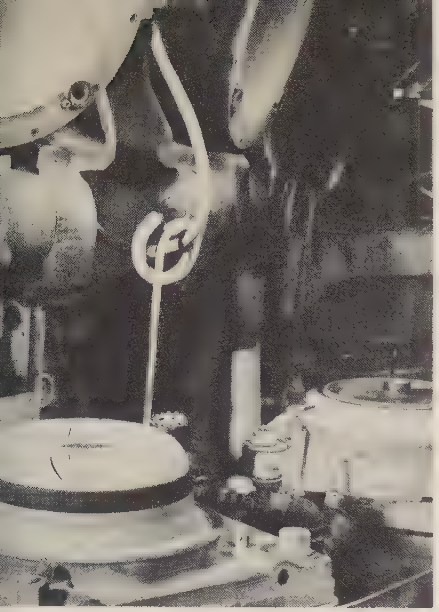

Fig. 7—Buick Dynaflow pump core assembly shown in position for permanent mold cope closing.

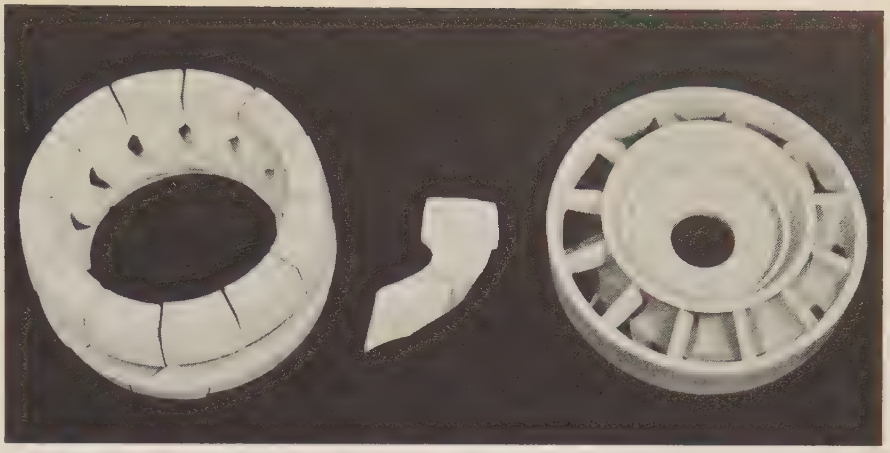

Fig. 9—Torque converter stator element castings (right) with the core assembly (left) required to produce the part as a semi-permanent mold casting.

box. After 14 minutes, the core is removed from the box. The core boxes are then blown clean with air and sprayed with oil, which acts as a parting compound. After removal from the core box, the cores are inspected for defects and placed on a tray which will receive the exact number required for a particular casting, as shown in Fig. 5. The trays are stacked and removed to a box drying oven for four hours.

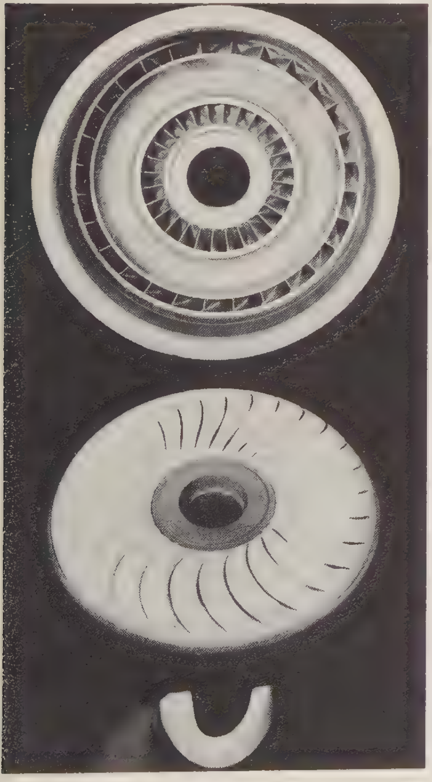

Fig. 8—Buick Dynaflow pump casting with the core assembly of foam plaster cores and drag core which was required to produce the part.

The drying temperature and time must be controlled because of its effect on core size. The foam plaster expands 0.0012 in. per in. during setting, and with drying temperatures of 400° F. or below, the cores contract to the original core box size. Of course, core size depends on the accuracy of the core boxes used; the plastic core boxes used in this process are made to ±0.0005 in. tolerances, in order to insure good core fits when 28 to 44 vane cores are assembled in a ring.

Fig. 6 shows the assembly of Buick torque converter pump vane cores in a drag, or lower casting box, core after drying. The vane cores are pasted into the drag core, and the paste is dried by placing the assemblies in a drying oven. After the second drying, the assemblies are placed on a permanent mold drag. The permanent mold cope, or mold cover, is closed over the core assembly and the molten aluminum alloy (355 type alloy) is poured into the permanent mold. Fig. 7 shows the Buick torque converter pump core assembly located in the permanent mold drag. A finished pump casting after cleaning and heat treatment is shown in Fig. 8 beside the core assembly which was required to produce it. An illustration of the use of vane cores without a drag assembly core is shown in Fig. 9. This torque converter stator is made by picking the vane cores in a core-setting fixture and placing them in a full permanent mold.

The foam plaster process has a number of production advantages over the use of other plaster processes. A wide range of permeability is available by changing the foam volume. The plaster cores can be processed only by drying in ordinary ovens without the necessity for high-temperature drying or steam-pressurized autoclaves. The dimensional accuracy and surface finish of the castings produced is comparable to those of the other processes.

Aluminum castings made in complete plaster molds have lower mechanical properties than those produced in sand or metal molds. This occurs because the refractory nature of plaster results in a slower solidification rate of the metal being cast in the mold. However, the permeability, high dry strength, and dimensional accuracy of foam plaster cores make them adaptable for use in semi-permanent mold castings. The mechanical properties of the foam plaster core, permanent mold castings approach the high strengths achieved from full permanent mold.

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Raising the Limits for Thrust Measurement in Jet Engine Testing

During testing of production jet engines and in the development of new engines it is necessary to measure accurately the thousands of pounds of developed thrust. The two elements of a laboratory test setup are a means of supporting the engine under test and a means of measuring the thrust forces generated. An advanced thrust measuring system uses flexible supporting members and a metering mechanism which uses a Wheatstone bridge to translate the physical movement of the thrust platform into an electronic signal. Accurate data obtained from this and other systems help in improving the performance of jet engines.

One of the important phases of turbo jet engine development is accurate measurement of thrust. Since thrust is a measure of the usable work developed by the engine, it is of prime importance to the aircraft as well as the engine manufacturer.

Design work on thrust measuring instruments, with respect to Allison turbo jet engine testing, started early in 1944 with a 1,600 lb thrust unit, and has evolved into systems capable of measuring several times that thrust. This increased range and desire to achieve more comprehensive, accurate data have made necessary entirely new instruments and linkages, the development of which is discussed herein.

A prime design criterion in any measuring device is accuracy. In the realm of thrust measurement, accuracy is affected by all of the various components of the system and by all of the dynamic and static forces which act on those components. The combination of these factors presents certain predictable and unpredictable errors, which can be minimized but cannot be entirely eliminated. It is therefore necessary to certify the system by accurate calibration both at the time of initial installation and at frequent intervals during operation to maintain the high quality of thrust measurement required. Certain basic design considerations such as range, durability, and ease of maintenance must be designed into a system in such a manner that they impose little effect on the ability to obtain satisfactory calibrations having good repeatability characteristics.

There are usually two major constituents in any thrust measuring system: (a) linkage required to support the engine and freely transmit the thrust force, and (b) a load reaction device which has the ability to convert thrust to a readable quantity.

Types of Support Linkages

Many types of thrust linkages have been used successfully and a few of the more common applications are described below.

The Floating Cradle

The floating cradle (Fig. 1) represents an early attempt to obtain a low friction device for thrust transmission. It consisted of a steel cradle supported from above by means of four rods. Thrust was transmitted through tension rods to a bell crank and hence to the load instrument. The bell crank in this case was designed having a mechanical advantage of two, which required the load cell to counteract a force half the magnitude of the engine thrust.

Many difficulties became apparent with this installation. The load device was subject to damage from the heat encountered in the combustion section of the engine and required shielding. The possibility of support rod or instrument damage due to major engine failure was ever present. The versatility of the cradle was poor, making observation, installation, and adjustment of the engine difficult.

The Parallel Linkage

The parallel linkage installation (Fig. 2) was the next attempt at achieving a rugged, durable arrangement. In this installation the engine was supported from a baseplate by means of the vertical compression members of the parallel linkage, which in turn supported the weight of the engine and cradle. The forward vertical member was designed as a bell crank, similar to the crank in

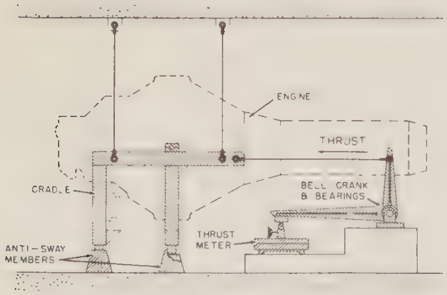

Fig. 1—Early thrust measurements were made with engine mounted in a floating cradle.

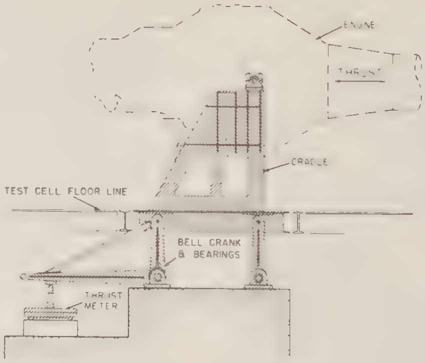

Fig. 2—The parallel linkage overcame some of the weaknesses of the floating cradle system.

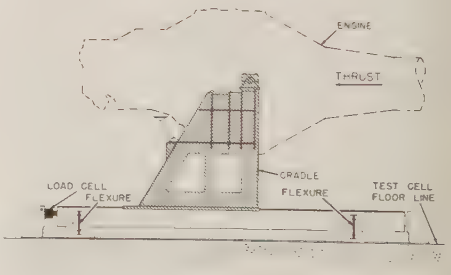

Fig. 3—Flexure linkage system as installed at Allison Division.

By **EUGENE F. COLDITZ**
Allison Division

How jet engine thrust is accurately measured

the floating cradle system. A careful adjustment was necessary to insure that the weight of the engine passed through the bearing and did not impart a moment on the lever arm. A pneumatic force, balance type load cell was used with both the floating cradle and parallel inkage systems.

The Flexure Linkage

Another system uses flexure linkage, and many variations are possible. Systems have been designed with the flexures n tension, compression, and shear depending upon the particular design requirements. One of the present systems nstalled at the Allison Division (Fig. 3) utilizes flexure members in which the weight of the platform and engine is supported in tension by the flexures. With his arrangement small movement, 0.005 o 0.010 in., is possible with very little esistance. This feature makes the strain gage or sealed hydraulic system paricularly adaptable, since each possesses he ability to counteract large loads with mall displacements.

A careful system analysis is required whenever flexures are utilized to insure hat the added weight of the engine does not impose uncalculated force components on the load device. As an example, it is desirable to place a tare load on the cell at the time of initial installaion, with no engine installed on the lexure platform. A practical solution is ere presented to show how the added ngine weight could impose a component in the direction of thrust and the pproximate magnitude of this force.

If that load were applied by deflecting he flexure rearward, it can be seen from ig. 4 that as the weight which is applied o the flexures changes, a new comonent in the direction of thrust is resent. This can be explained more fully by the analysis which follows:

By cutting the beam at the point of inflection and considering it as a cantilever beam having the load applied at the end, the deflection Υ becomes

$$\Upsilon = \frac{F_1 L_1^3}{3EI}$$

where

F_1 = load applied
L_1 = length of the beam (in this case, one half of the total flexure length)
E = modulus of elasticity
I = moment of inertia

from which

$$F_1 = \frac{3\Upsilon EI}{L_1^3}$$

Taking moments about Z, essentially $M_1 = M_2$ for small displacements, and the component in the directions of thrust due to weight is F_2.

$$F_2 = \frac{\Upsilon W}{L_1}$$

where

W = weight.

The total load, therefore is the summation of the two forces, or

$$F_3 = F_1 + F_2$$

where

F_3 = applied load for given deflection
F_1 = force required to deflect beam through Υ distance
F_2 = force required to counteract horizontal component of tension

or, summarizing,[1]

$$F_3 = \Upsilon\left(\frac{3EI}{L_1^3} + \frac{W}{L_1}\right).$$

Therefore as W increases F_3 increases. For the total flexure length L, F_3 would produce deflection equal to a. This is a constant correction throughout the range of the instrument and is accounted for during calibration.

Types of Thrust Meters

The second major constituent in a thrust measuring system is the thrust-meter or load cell. Many types of these devices are at present commercially available. Some of the categories into which they fall are:

(a) The null position force balance diaphragm using either pneumatics or hydraulics as a loading and transmitting medium.

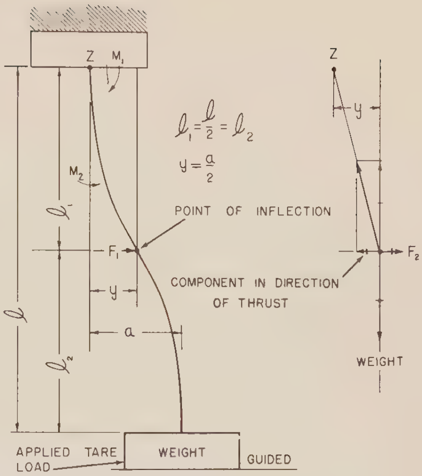

Fig. 4—Analysis of forces on flexure illustrated in Fig. 3.

(b) The closed hydraulic system utilizing a cylinder and piston arrangement with hydraulic transmission.

(c) A calibrated cell employing the strain gage principle and utilizing the measurement of resistance changes.

(d) Mechanical knife edge and beam balance scales which may require direct observation.

Diaphragm-type Meter

The pneumatically operated force balance diaphragm was the first device utilized at Allison and is still being used on some installations. At the time the first thrust systems were being designed, no acceptable commercial units were available, and an extensive research program was carried on in the development of an air-operated force measuring instrument.

The unit developed consists essentially of a sealed diaphragm (Fig. 5) across which a regulated differential pressure is maintained. A positioner is installed to maintain the diaphragm in the neutral, or null, position. This is necessitated because the slightest change in diaphragm position causes a corresponding change in the effective area of the diaphragm.

An illustration of the change in the effective area can be seen in Fig. 6. If the diaphragm is considered to be a perfectly flexible member which is incapable of transmitting force except by tension, it is apparent that forces

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[1] A more complete solution may be deduced from Roark, Raymond J., *Formulas for Stress and Strain* (New York: McGraw-Hill Book Co., Inc., second edition, 1943), p. 133.

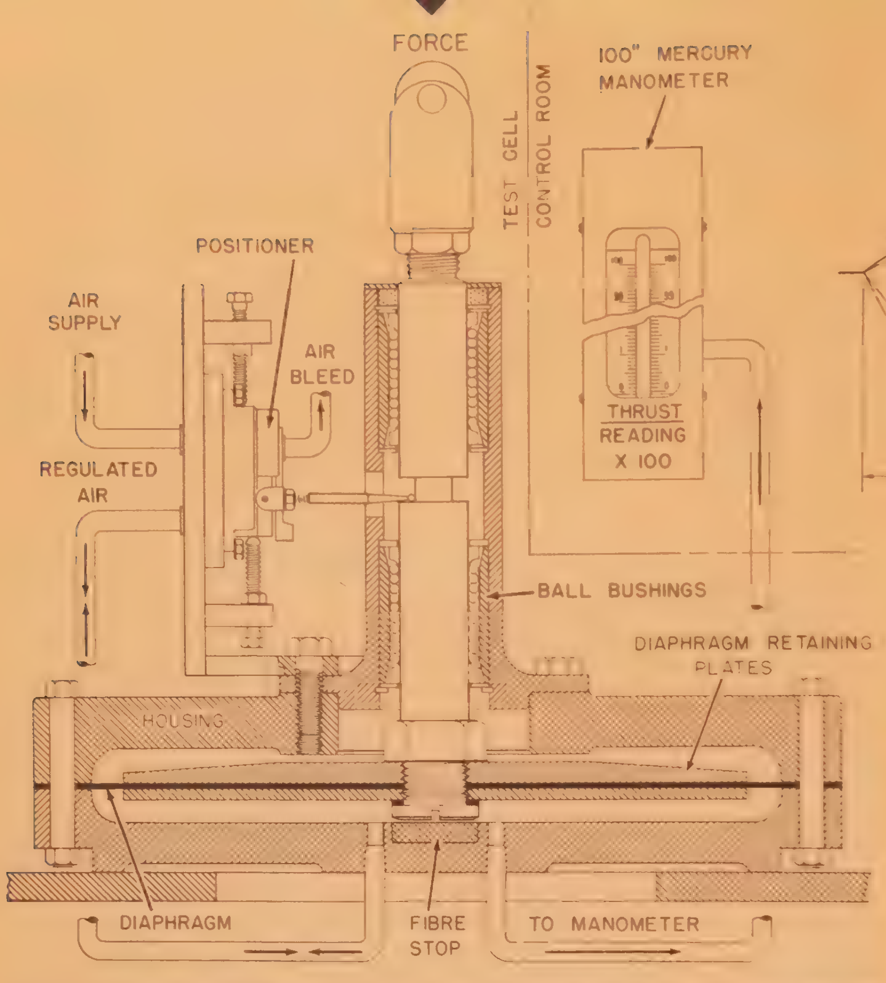


Fig. 5—First thrust meter developed at Allison was an air-operated instrument utilizing the force-balance principle.

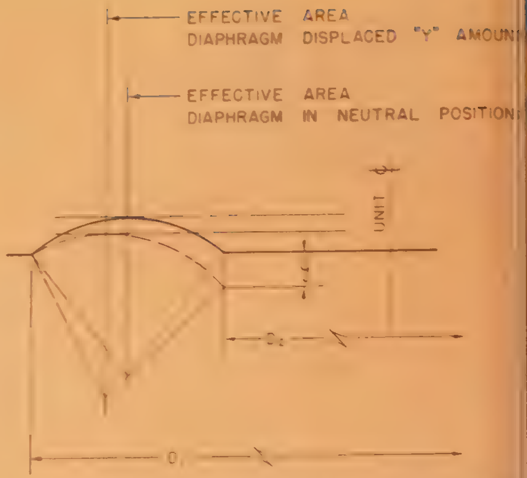

EFFECTIVE AREA DIAPHRAGM DISPLACED "Y" AMOUN
EFFECTIVE AREA DIAPHRAGM IN NEUTRAL POSITION
UNIT
D_2
Y
D_1

Fig. 6—A change in diaphragm position change element's effective area.

Fig. 7 (right)—Experimental curve of diaphragm effective area provides calibration data.

developed on the diaphragm outside of the point of contact of a plane which is parallel to the main diaphragm and tangent to both lobes formed by the deformation of the diaphragm, must be transmitted to the outer case.

Therefore the effective area of a flexible diaphragm used in this type of thrust meter can be defined as that area which when multiplied by the differential pressure across the diaphragm gives the load which is counteracted by the instrument. If the diaphragm is then maintained in the neutral position the effective area A_E can be closely calculated by means of the following formula.

$$A_E = \frac{\pi}{4}\left(\frac{D_1 + D_2}{2}\right)^2$$

where

D_1 = case bore diameter

D_2 = diaphragm retainer outside diameter.

Small errors are possible because of diaphragm material characteristics, but an overall accuracy of ±0.25 per cent can be obtained.

To illustrate this further, the Allison thrust meter has the following specifications: (a) outer case bore diameter, 12.0625 in., and (b) outside diameter of diaphragm retainer, 10.6875 in. Solving for A_E,

$$A_E = \frac{\pi}{4}\left(\frac{12.0625 + 10.6875}{2}\right)^2$$

$$= 101.624 \text{ in.}^2.$$

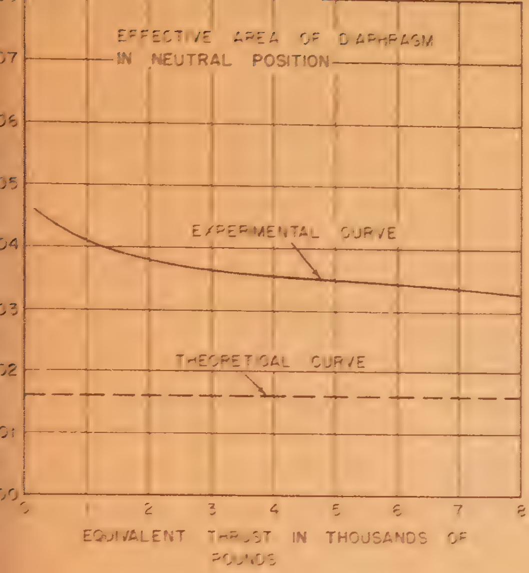
As shown in Fig. 7 the actual effective area from a dead weight calibration, maintaining the diaphragm in the neutral position, gives a curve which approaches the theoretical curve but does not reach it within the range of the instrument. The experimental curve is, however, a complete system calibration which does possess good repeatability characteristics

The pneumatic-operated sealed diaphragm is very well suited to thrus measurement during steady state oper tions. It is not particularly adaptab to thrust measurement during engi acceleration because of the pneumat lag inherent in the system. This limit tion was a contributing factor causi the transition from this type instrume to the strain gage load cell.

The Strain Gage Load Cell

A more recently developed thrust measuring device being used in new installations is the strain gage load cell (Fig. 8). It transmits changes in thrust into electrical energy by employing a high strength load carrying member into which are cemented wire strain gages. These strain gages undergo changes in resistance proportional to applied strain or thrust.

The strain gages comprise the four legs of a Wheatstone bridge. Under no-thrust static conditions the bridge is balanced. With a voltage applied to the input o the bridge, the output is zero. When thrust is applied to the load element it is transmitted through the cement to the strain gages changing their resistance and unbalancing the bridge. The resulting voltage, which is proportional to thrust, is transmitted to an indicator. The indicating instrument operates o



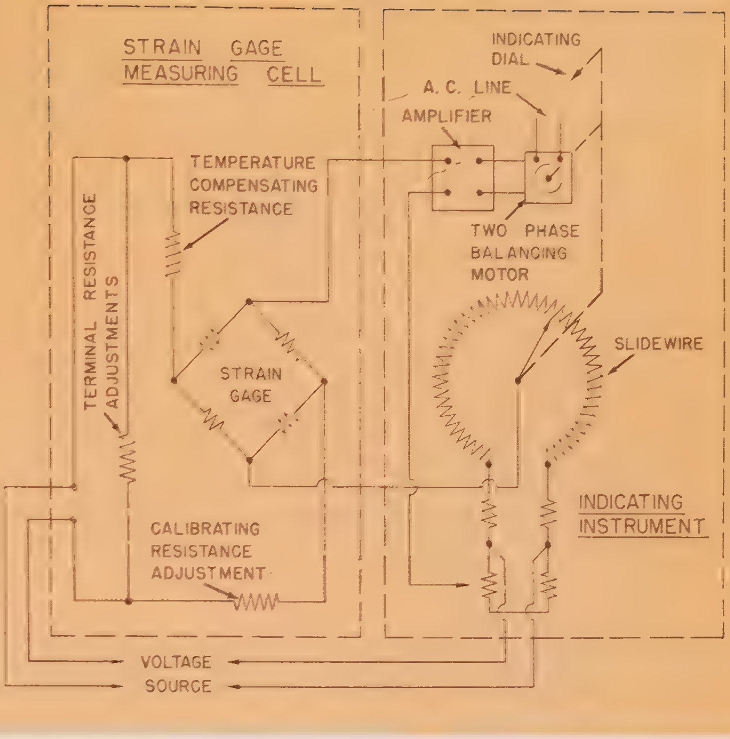

STRAIN GAGE MEASURING CELL
INDICATING DIAL
A. C. LINE
AMPLIFIER
TEMPERATURE COMPENSATING RESISTANCE
TWO PHASE BALANCING MOTOR
TERMINAL RESISTANCE ADJUSTMENTS
SLIDEWIRE
STRAIN GAGE
INDICATING INSTRUMENT
CALIBRATING RESISTANCE ADJUSTMENT
VOLTAGE SOURCE

Fig. 8 (right)—More recent thrust meter uses output of Wheatstone bridge to actuate indicator circuitry.

ne null balance principle. Any voltage utput from the Wheatstone bridge is mplified and used to drive a balancing notor in a measuring bridge of the nstrument. The motor is directly con- ected to a slidewire contactor and an ndicator. The motor senses the voltage nbalance of this measuring bridge and rives the slide wire contactor to a posi- on which balances the input from the oad cell. The indicator then is read in erms of thrust. The calibrated accuracy f this system is ±0.1 per cent.

pplication and Limitations

Errors due to temperature changes are consideration in all thrust measuring evices. Strain gages are particularly usceptible to these temperature changes nd a temperature compensating ele- ent is usually incorporated into the nstrument.

All of the devices and systems dis- ussed can have definite application in test program. Design requirements ictate which of the systems will be most uitable for any particular force measur- g problem. Both of the specific types of stems which were discussed in this eport have definite application in jet ngine thrust measuring.

The cost of the pneumatic system is sually lower and in many applications is suitable. The ability to follow ngine thrust rapidly during accelerations is not present with the pneumatic system discussed. Rate of response could be increased by the introduction into the system of a transducer which senses the pneumatic signal at the meter and transmits it electrically to the data recording center.

The strain gage instrument discussed has very rapid response to engine thrust changes and has been used successfully to ascertain the rate of thrust increase during accelerations. With the increased versatility and speed of response, indications are that strain gage or the sealed hydraulic system, the two being quite similar in their thrust measuring ability, show good promise of being readily adaptable to increasing requirements of thrust measurement in jet engine testing.

Conclusion

Considerable study and development have gone into solving thrust measurement problems for jet engine production and research. Progress so far has been satisfactory in that new developments have not lacked for a means of testing performance. In this testing field, as indeed in all evaluation problems, progress must remain well ahead of actual developments in jet engines. The lessons learned so far have established suitable working patterns for the increased demands which will be placed on new thrust measuring instruments.

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How the Autronic-Eye Automatic Headlamp Control was Designed to Meet Driver Requirements

By GEORGE W. ONKSEN
Guide Lamp
Division

Making the mechanical slave do the master's job better

Man, as a driver, reacts to stimuli of approaching car lights and switches to the lower beam, restoring upper beam after the lights have passed. Engineers, always responsive to opportunities for making man's actions simpler and less frequent, studied this servomechanism pattern and established performance criteria for an automatic headlamp control. Then they designed, tested, and put into production a device which performs this heretofore human function even better than man. The result is the Autronic-Eye automatic headlamp control, basically an unselfish device in that it makes the driver truly a gentleman of the night highways, dimming always on time. It also gives the driver upper beam more of the time than he would have the patience to claim as his right and adds to motoring safety.

HEADLAMP glare has been a continuing problem ever since electric headlamps have been used on automobiles. A beam which illuminates the road far ahead for safe driving is too bright for the approaching driver.

The first headlamps had only one beam. Control was attained by a resistor which was switched in and out of an electric circuit to make the beam dim for approaching cars. Later, two beams were used: an upper beam designed for clear road driving and a lower beam designed to reduce glare when passing.

As the years passed, headlamps were standardized, accuracy was improved, and inspection and service facilities were developed with the result that today the glare problem is largely a matter of proper headlamp usage.

Open road driving conditions change so rapidly, however, that the correct choice of beam calls for rather careful attention on the part of the driver. All drivers are not willing to devote that much attention to the job. A few drivers do not dim until they are signaled, and many drive constantly on their lower beams to avoid using the foot switch. Both habits are dangerous. Experience indicates that it is difficult to get drivers to pay more attention to their driving, either through education or law enforcement.

Forty million cars were using the highways at the end of 1952, which was about 40 per cent more than during the first post war year of 1946. Present traffic volumes, then, point to the desirability of an automatic method to control headlamp glare for the safety and convenience of American motorists. Automatic headlamp control by means of the Autronic-Eye automatic headlamp control was introduced on certain 1952 models of General Motors cars.

The design goals for the Autronic-Eye control were to utilize a light measuring device to achieve complete headlamp control under widely varying conditions. Some of the conditions which the final design had to meet were:

- The device should switch to the lower beam promptly when subjected to sufficient light, and should switch back to the upper beam promptly when light is removed.
- The device should retain the lower beam when the approaching driver dims.
- The device should dim for cars on curves but should not dim excessively for extraneous light at the roadside.
- The driver should be able to switch to the lower beam for city use and for following another car when there is insufficient light to retain the lower beam automatically.
- The driver should be able to obtain the upper beam for signaling and for travelling at dusk when there is too much light from the sky for the device to switch to the upper beam automatically.
- The device should not be impaired when operated in the daytime.

For a considerable number of years, automotive engineers have been convinced that automatic headlamp control devices offered possibilities for solving the glare problem—if such devices could be made to function properly. The outlook was far from encouraging, considering that the brightness of an oncoming upper beam was many times that of an oncoming lower beam. Likewise troublesome was the variation in brightness caused by the deterioration in non-sealed beam lamps. Even so, promise of real improvement in glare was so obvious that the idea of automatic headlamp control could not be ignored.

At the start, the problem was to develop something that was sensitive enough to dim for lower beams at a safe distance. Satisfactory sensitivity was achieved by using a multiplier phototube which is capable of about one million times the sensitivity of standard vacuum phototubes. As sensitivity was increased it was found that extreme variations in brightness of oncoming headlamps was not nearly as serious as anticipated because very few roads are straight and level for any great distance. Increasing sensitivity, however, uncovered other problems in the fields of electricity and optics which had to be solved in designing a satisfactory device.

Design of the Control

The production design of the Guide Autronic-Eye headlamp control did meet all of the required specifications. How the various requirements were met can be understood after a consideration of the circuit diagram for the equipment (Fig. 1).

Energy is provided by the car electrical system through the standard light switch. The voltage is applied to the ballast tube, to the primary winding of the transformer, and then through a vibrator to the ground.

The transformer has two secondary

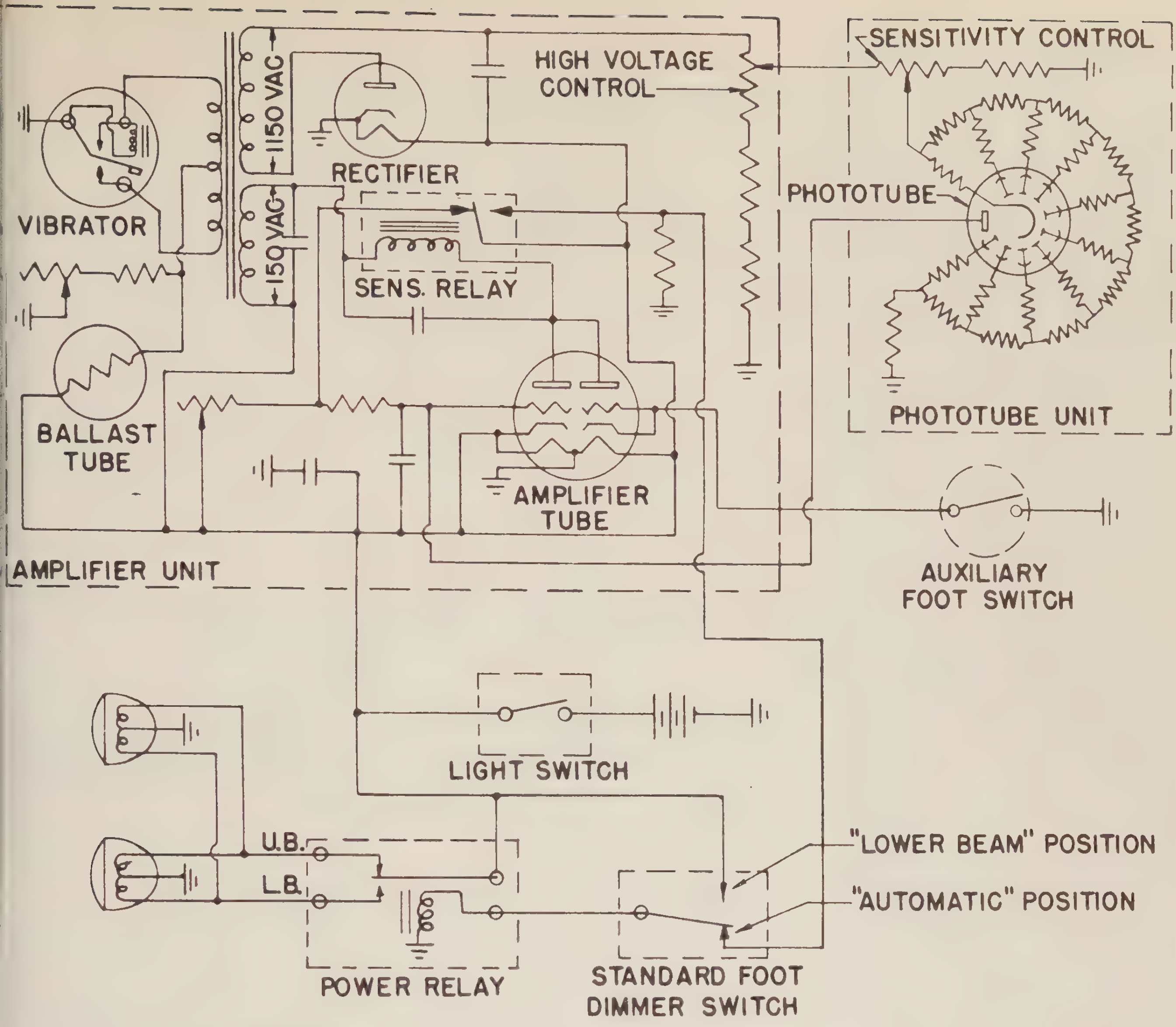

Fig. 1—Two secondary transformer windings supply a high voltage, rectified for operating the phototube, and a low voltage to supply the amplifier tube and sensitive relay. Light on the phototube causes the sensitive relay to open, switching a comparatively larger load resistance into the phototube circuit. This gives the device about ten times greater sensitivity in the lower beam position than in the upper beam position.

windings, one producing approximately 1,150 volts a-c and the other approximately 150 volts a-c. The higher voltage s rectified to produce approximately 1,000 volts d-c across a load resistor network. A high voltage control is adjusted to supply the necessary voltage for the phototube unit. A sensitivity control in the phototube unit adjusts the high voltage to compensate for variations n phototubes. The voltage is applied to he various dynodes in the phototube hrough a voltage divider network.

The 150-volt secondary winding of the ransformer supplies power for the ampliier tube and the sensitive relay. In the absence of light on the phototube, the amplifier tube passes enough current hrough the sensitive relay to close it. The presence of light causes the phototube to pass a current through a load resistance which develops a negative bias voltage on the amplifier tube control grid. This causes the amplifier tube to reduce the current through the sensitive relay. When the current is reduced sufficiently, the sensitive relay opens. When the sensitive relay opens it switches a much larger load resistance into the phototube circuit and in this way causes the device to be about ten times as sensitive in the lower beam position as it is in the upper beam position.

When the standard foot dimmer switch is in the AUTOMATIC position, the sensitive relay opens and closes the power relay which switches the headlamps between the upper and lower beams.

When the push-button type auxiliary foot switch is depressed it closes the sensitive relay through an added section in the amplifier tube, and overrides the automatic control to provide the upper beam even when bright light is on the phototube.

When the standard foot dimmer switch is depressed and released as in changing from upper to lower beam, the power relay is closed directly from the light switch and holds the headlamps on the lower beam regardless of the position of the sensitive relay.

The optical design of the phototube

unit is shown in Fig. 2. A condensing lens focuses light through an amber filter and through an opening in a mask to a multiplier phototube. The condensing lens is corrected for spherical aberration and focuses the light from approaching headlamps to a point in the plane of the mask. The vertical and horizontal angles through which the device responds to light are limited by the size of the opening in the mask, and the sensitivity cuts off abruptly when the point of focused light passes the edge of the mask opening.

An *S4* (blue sensitive) cathode surface is used in the multiplier phototube because red sensitive surfaces are not compatible with the materials used in the amplifying sections. However, the high sensitivity of the multiplier phototube permits the use of an amber filter which absorbs blue light and moves the effective response toward the red end of the spectrum.

Fig. 3 shows a series of color sensitivity and emission curves of the *S4* cathode surface, the amber filter, an incandescent bulb, skylight, and the *S4* surface through the amber filter.

The curves show that the relative emission of skylight is much better than from an incandescent bulb near the violet end of the spectrum while the incandescent bulb is better near the red end. The curves also show that the amber filter blocks off the light near the violet end and thus reduces skylight much more than incandescent light. The amber filter permits the device to function sooner at dusk by reducing the effect of skylight.

Performance Criteria

Some of the performance requirements of an automatic headlamp control have already been mentioned. The Autronic-Eye control met these and other criteria by means of the circuit described above. The design problem was to insure that in the achievement of one specification others were not made impossible.

Switching to and Holding Lower Beam

The basic requirement is that the device switch to the lower beam promptly when subjected to sufficient light, and switch back to the upper beam promptly when light is removed. Rapid dimming is especially important in situations where an approaching car comes suddenly in view, as, for example over the crest of a hill. The device must not only switch to dim, but must hold in this condition when the approaching car dims. If an approaching car dims at some distance, the automatic device must switch to and hold the dim position until the oncoming car has passed.

These basic requirements were designed into the Autronic-Eye control by adjusting sensitivity to dim at a certain optimum sensitivity and then to hold the dim position with about *ten times* as much sensitivity. The multiplier phototube provides the sensitivity for this technique, and, at the same time, permits rapid operation in both the dimming and upper beam recovery cycles.

Dimming on Curves

The device should dim for cars on curves but should not dim excessively for extraneous light at the roadside.

The desire for dimming on curves conflicts with the desire to restrain the device from dimming for extraneous light at the roadside. The first desire can be satisfied by making the device responsive to light at wide angles to the sides while the second desire demands that the device must not be sensitive to side light.

The Autronic-Eye control represents a compromise between these two conditions, designed to provide the narrowest possible sideways response angle consistent with proper operation on curves

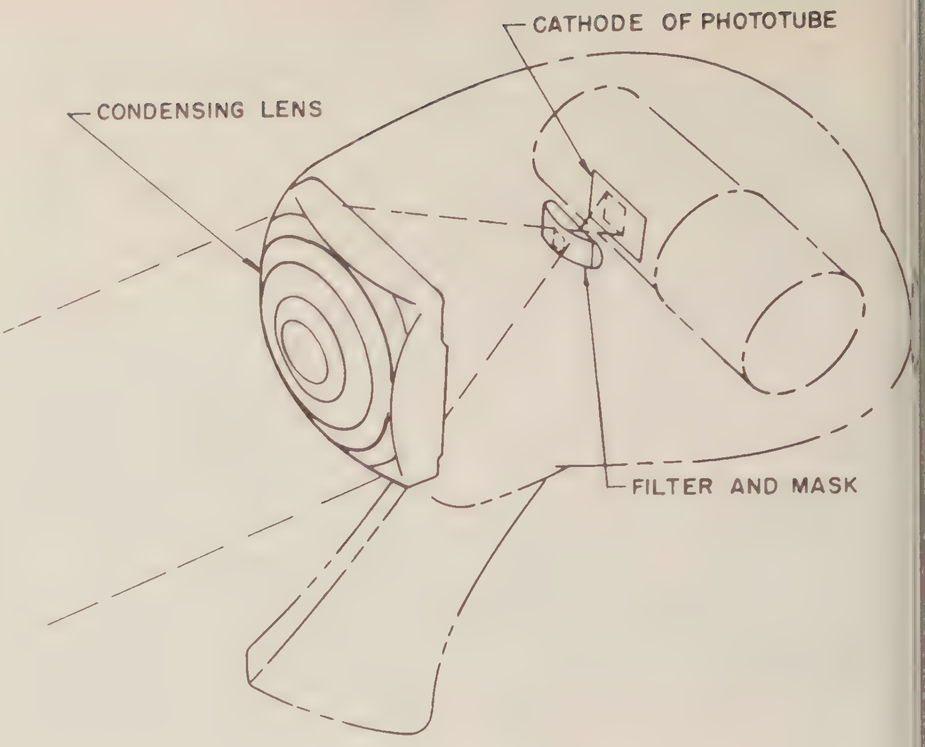

Fig. 2—The optical design of the phototube unit illustrates how light from approaching headlamps is condensed and passed through an amber filter which corrects for skylight. The mask opening determines the vertical and horizontal angles o response.

Disregarding Road Reflection

The device should not be affected by variations in the reflectivity of road surfaces, and the device must function with normal variations of car loading.

Headlamps illuminate the road ahead and the road brightness reflecting back to the driver varies from almost nothing on wet asphalt to a considerable amount on dry gravel or fresh snow. A device which is sensitive enough to retain the lower beam after the approaching driver dims is necessarily sensitive enough to be greatly affected from road reflection, unless the downward response angle is carefully controlled. If too much light from the road is permitted to reach the phototube, the device will stay on the lower beam. At the same time, the sensitivity response angle must extend enough below horizontal so that the device will function properly under conditions of normal car loading.

The Autronic-Eye control has a lens and mask system which provides a sharp lower cut-off. The cut-off is aimed as low as possible without incurring inter-

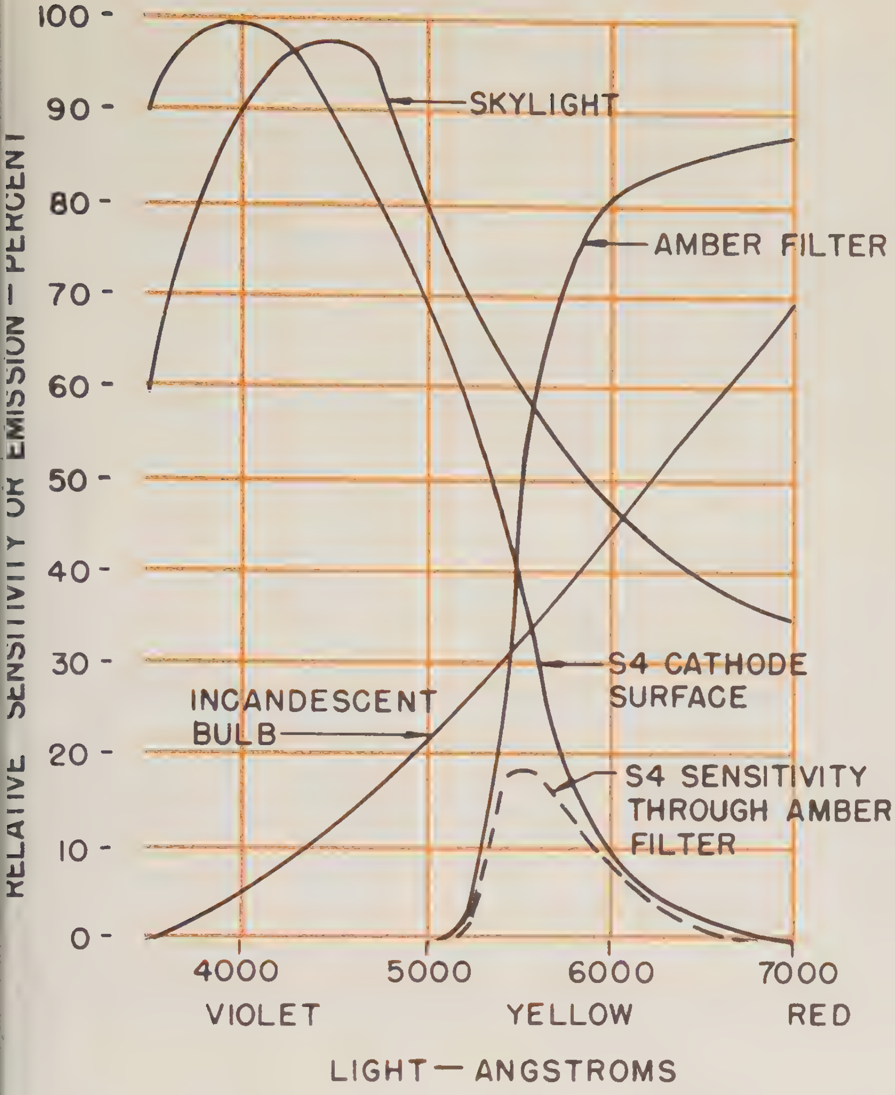

Fig. 3—How the amber filter reduces the effect of skylight is shown by the sensitivity and emission curves of an *S4* cathode surface, an incandescent bulb, an amber filter, skylight, and an *S4* surface through an amber filter. The blue, *S4* cathode surface is used in this device because red sensitive surfaces are not compatible with materials used in the amplifying sections.

ference from road reflection. This aim is ow enough to stand the upward tilting caused by normal car loading without ndue loss in sensitivity. The location of he phototube unit on the car instrument panel is shown in Fig. 4.

Disregarding Weather

The device should function under conditions of adverse weather such as rain, snow, and fog.

The light from approaching cars is somewhat diffused by rain on the windshield but fortunately the device is not affected appreciably in sensitivity. Actually, there seems to be an increase in light from the approaching car, probably due to reflections from wet pavement adding to the normal direct light coming from the lamps and this may balance out any loss from light diffusion. In bad weather drivers may devote full attention to driving, without having to pay attention to their headlights. Very little sensitivity is lost in moderate snow and fog. If the snow or fog is severe, the back reflection of the vehicle headlamps from the snow or fog particles is sufficient to retain the vehicle headlamps on the lower beam.

City Driving and Following

The driver should be provided with a means of obtaining a lower beam for use in the city and when following another car, when there is insufficient light to retain the lower beam automatically.

The amber filter, mentioned above, corrects, as much as possible, the relatively poor red sensitivity of the multiplier phototube. With this combination, the device retains the lower beam satisfactorily when following a modern car with relatively bright tail lights, but it does not retain the lower beam at a sufficient distance for many older tail lights, and it does not dim for any of them. The Autronic-Eye control is connected to the standard foot dimmer switch so that it functions automatically in one position only. The other position of the foot dimmer switch provides a fixed lower beam. When necessary, the driver may use the foot dimmer switch to lock the device on the lower beam. One of the times when a continuous lower beam is desirable is when following another vehicle.

Using the Upper Beam

The driver should be provided with a means of obtaining an upper beam for signaling and at dusk, when there is too much sky light for the device to switch to the upper beam automatically.

After the automatic headlamp control has dimmed, very little light is required to retain the lower beam. There are occasions, particularly at dusk when sky light is still effective, when there is sufficient light to retain the lower beam but not enough to cause the device to dim. On such occasions, the driver may prefer the upper beam. This automatic headlamp control includes a push-button auxiliary foot switch to over-ride the automatic control and provide the upper beam regardless of light conditions. This switch resets the sensitive relay to the upper beam position, and when the foot switch is released the device remains on the upper beam unless there is sufficient light ahead for dimming. Also, the overriding switch may be used to signal approaching drivers if they forget to dim.

Warming-Up Action

The device should provide the lower beam during warm-up.

Most electronic devices require a moderate warm-up time during which period they do not provide automatic control. Because vehicles usually are operated in areas of opposing traffic during the warm-up period, it is desirable to have a fixed lower beam until the automatic control is functioning. This period of no control, therefore, must be considered in designing an automatic control. The Autronic-Eye control requires ten to 15

Battery Voltage	Per Cent Sensitivity (Dimming Distance)
5.5	93
6.0	100
6.5	100
7.0	102
7.5	102

Table I—Voltage regulation for the multiplier phototube is provided by a current regulator (ballast tube) in the primary of the transformer. The sensitivity of the device is only slightly affected by the normal changes in car battery voltage, as shown in this table.

seconds warm-up time for the rectifier and amplifier tubes. The rectifier tube controls the high voltage to the phototube, and the amplifier tube provides the current to the sensitive relay. The sensitive relay is in the lower beam position when the amplifier tube current is off. The rectifier tube is adjusted to warm up ahead of the amplifier tube so that the phototube is in control before the amplifier tube can operate the sensitive relay to the upper beam position.

Operating in Daylight

The device should not be impaired when operated in the daytime.

Most phototubes and particularly multiplier phototubes must be protected from damage from bright light. A multiplier phototube can easily destroy itself if it is permitted to pass too much current. Occasionally, a driver will operate his automatic headlamp control during the daytime. There are places, for example through the tunnels on the Pennsylvania Turnpike, where a driver is requested to turn on his headlamps in the daytime. It is common to see cars travel a considerable distance beyond the tunnel before their lights are turned off. Since the device is connected to be turned on with the headlamps, the phototube is functioning during this period.

The dynodes of the multiplier phototube are connected through individual protective resistors so that the current through each dynode is limited to a very safe value. These protective resistors do not affect the multiplier phototube function at night because the current values are too small to cause detrimental voltage changes to the dynodes.

Varying Battery Voltage

The device should be relatively insensitive to changes in battery voltage.

Car batteries vary about 30 per cent in voltage. Multiplier phototubes are very sensitive to voltage changes; in fact, a ten per cent increase in voltage doubles the output. In order to obtain satisfactory performance on a car, the Autronic-Eye control is designed with voltage regulation. Regulation is obtained by using a current regulator (ballast tube) in the primary of the transformer. Table I shows how variations in battery voltage affect sensitivity. The dimming distance varies from about minus seven per cent to plus two per cent.

Conserving the Generator

The device should use a minimum of current to avoid exceeding the generator capacity.

Car generators are designed to keep the batteries charged under given load conditions and, ordinarily, they do not accommodate very much extra load. For this reason, the device is designed to use a minimum of current. The 6-volt models use 2.1 amperes in the upper beam position and 2.5 amperes in the lower beam position. The 12-volt models use 1.2 and 1.4 amperes in the upper and lower beam positions, respectively.

Withstanding Motoring Hardships

The device should withstand the abuses of automotive service, which include heat, cold, vibration, moisture, and dust.

Extensive field testing and tests on the Belgian Block road at the General Motors Proving Ground near Milford, Michigan, indicated that special precautions were required to make the automatic headlamp control rugged enough for automotive service. Accordingly, the chassis was reinforced and condensers were anchored to avoid wire breakage. Special lead construction was used in the vibrators to avoid internal wire breakage. High temperature condensers were used because of high engine heat on hot days. The amplifier was enclosed to protect it from moisture and dust. Special alloy points with wiping contacts were used on the sensitive relay to avoid tarnish. Special alloy points were used on the power relay to handle the headlamp load. Special materials were used in the phototube base to avoid electrical leakage due to moisture. Fig. 5 shows th general location in the car of the prin cipal units of the Autronic-Eye contro

Experiences with the Autronic-Ey device indicate that extensive field testin on cars is required to locate and correc weaknesses in equipment of this nature Such testing is common in the automo tive field.

Servicing Ease

Service facilities should be availabl to adjust the device in the field.

An automatic headlamp control basically a light measuring device. I dims with a particular amount of ligh and switches back to the upper bear with a much smaller amount of ligh The value of light at each operatin point, therefore, is important and mus be obtainable in the field for servic adjustments. Secondly, the phototub unit must be aimed straight ahead an must be adjusted in the vertical plan because of the significance of the lowe edge of the response angle.

Two pieces of test equipment we developed for servicing this automati headlamp control: a test lamp for sen tivity adjustments and an aiming devic for aiming the phototube unit. The te lamp projects light against the phototub cathode in about the same manner headlamps under operating conditio The brightness of the test lamp adjusted to specific values by means of meter. One brightness is used to adju DIM sensitivity and a different brightnes is used in making HOLD sensitivity ad justments. (The latter determines th point where the device switches back t the upper beam.)

The aiming device is a mechanic fixture which aims by means of a level when located on top of the phototub

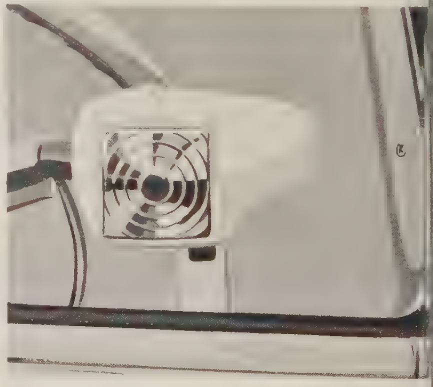

Fig. 4—Phototube unit mounted inside the ca on the instrument panel to left of the driver' position.

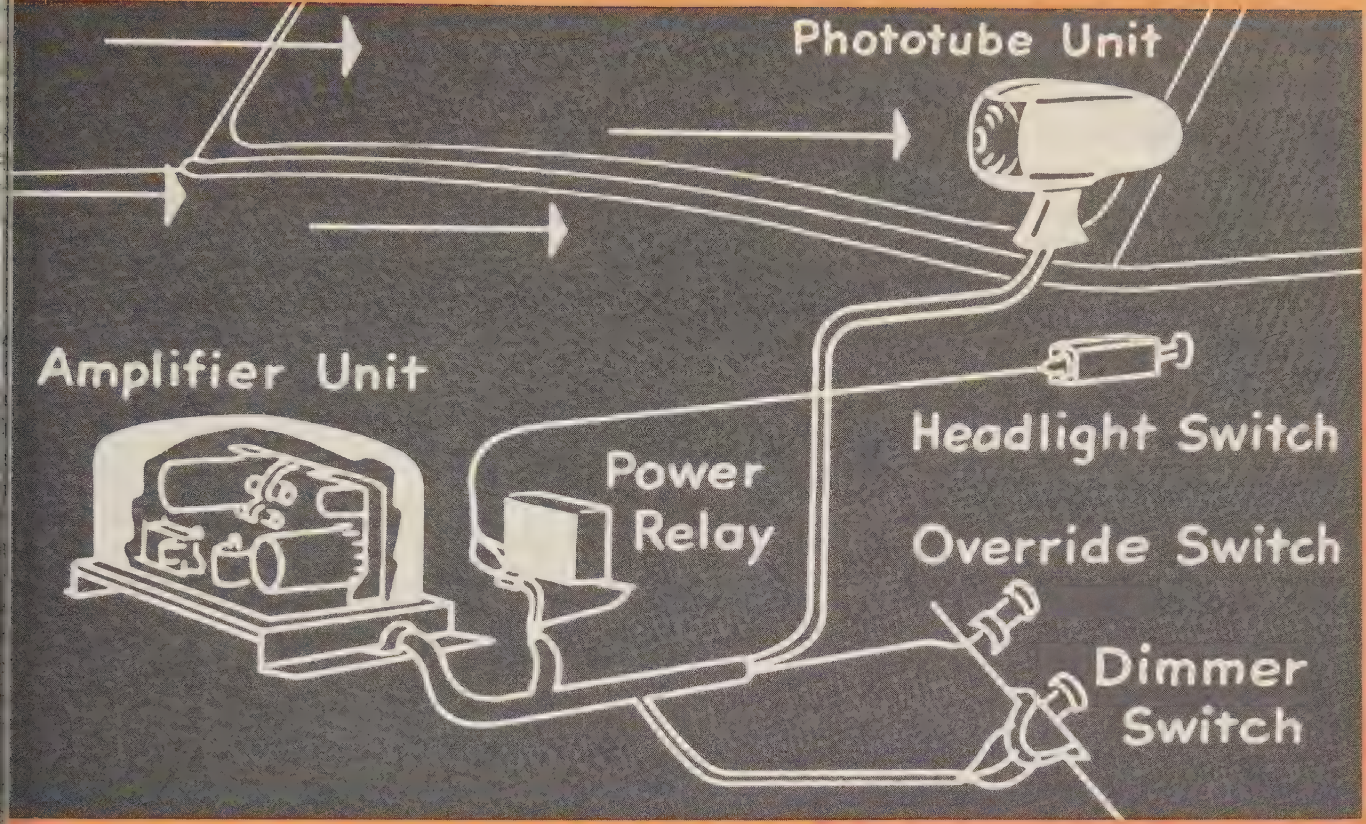

Fig. 5—Amplifier unit and power relay are located under the car hood, as shown in this sketch of the principal units of the Autronic-Eye control.

unit. The fixture contains an aiming dial which is adjusted to a code number stamped on a name plate underneath the phototube unit. The code number permits adjustment of the level to compensate for variations between the top surface of the phototube unit and the lower edge of the response angle. The code number is stamped at the factory. The bottom edge of the response angle is determined in an optical fixture by means of test lights after which a master level is placed on the phototube unit to find the code number. In this manner, an optical aim of the response angle is converted at the factory into a mechanical aim, and then the mechanical aim is used for field service.

Due to the high sensitivities required in automatic headlamp control devices, satisfactory operation is largely a matter of proper adjustment. The importance of adequate field service facilities, therefore, cannot be over-emphasized.

Summary

Experience during the first year of production demonstrates that, in complying with all of the above requirements, the Autronic-Eye automatic headlamp control offers real possibilities for improving the glare problem.

Public acceptance has been unusually good, particularly since an owner's first thought is that he is spending money for a device which only benefits the other fellow. He quickly learns, however, that the device does even more for him than for the approaching driver. He finds that the device gives him an upper beam more often than ever before in spite of the fact that it always dims for approaching cars.

By relieving the driver of the burden of operating his headlamps, the Autronic-Eye control makes night driving more pleasant and safe.

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Putting a New Car into Production

By EDWARD T. RAGSDALE
Buick Motor Division

Engineers, many others, team up for complex manufacturing job

When Eli Whitney invented mass production his basic principle was interchangeability of standard parts. Today's application goes much farther to achieve a good product at minimum cost. It requires the skillful combination of methods, men, machines, and materials. The first shiny new model, as it drives off the assembly line, contains thousands of parts and represents the work of scores of plants and departments. Yet at that same moment, production men already are preparing to make next year's model.

In any new model planning, the first consideration is the *announcement date* for the new car. Practically every factory operation is contingent upon the day the new model makes its appearance. Using the announcement date as a sort of "D Day," a schedule is set, backing off the number of weeks and days required to build a sufficient number of cars to supply dealers with a representative display of new models for introduction to the public. That establishes a date for start of production. This date is used in turn to back off the number of months, weeks, and days required for die tryout, for tooling tryout, and for pilot assembly operations. All of these operations are necessary for assurance that all parts will assemble in proper sequence with a minimum of effort and time. This date—the start of production—is the point at which tooling and plant rearrangement must be completed. Every operation preceding this date is pin pointed upon it.

A year's work goes into the preparation for new model production. As many as 15,000 parts are required to assemble each car. At Buick, there are 99 factories and separate organizations which team up to turn out new cars. Planning, tooling, and putting a new model into production is, then, a complex, complicated job.

If the new model requires the employment of additional people, such important functions as personnel, employment, medical, and cafeteria facilities will be involved. Salvage and waste disposal will be affected under certain conditions and an unanticipated increase in schedule will affect plant trucks, tubs, containers, garages, power equipment, and such facilities as air compressors, layout, and physical aspects of many factories. Safety, Fire Protection, Plant Protection—all these Departments have a definite function in almost any new model program.

After management has approved the final design, Engineering hands over to Manufacturing several acres of blueprints representing two, three, or more years of work up to this point. The announcement date has been set by the Sales Department. Several thousand new models must be in the hands of dealers on that date to show the public. What's more, the production rate will have to hit a maximum as quickly as possible after the announcement date to give dealers a stock of cars to meet the rush of orders that follows announcement. By that time, production test models will have been running, tool and machine tryouts will have been made, and countless hundreds of other major changes will have occurred.

What are the steps in the production of a new model? The first step takes place during the engineering design of the new model—before it ever reaches the production stage. Close coordination with Engineering is the first job of Production so that the final design is one which can be manufactured efficiently at a minimum reasonable cost.

The production activity begins when engineering drawings and parts lists are sent to Standards, to Cost, and to the Master Mechanic. In addition to these, the principal functions are Purchasing, Metallurgy, Process, Production Control, Accounting, Traffic, and Assembly.

Noting the variety of these functions, it will be interesting to observe later in the story an important conclusion affecting new model production.

Make or Buy—The Key Words

Engineering, preparatory to releasing for production the various parts of the new model, submits comparative parts lists to Cost and drawings of proposed parts to Standards, which together compile cost data such as those involving time, material, tools, and equipment. If a part is not new there is a re-examination of whether it will continue to be purchased or made at Buick, whichever was the case with the current part. If the part is new, and there are a great many of these in every new model, Standards confers with the Master Mechanic, with Manufacturing, and with management to decide whether it should be purchased or made.

Those words—make or buy—are heard almost daily in new model preparation and they are extremely important. The decision on each is a vital key to the eventual success of the new model.

If the decision is to purchase, Standards forwards drawings to Purchasing for development of quotations. If the part is to be made at Buick, Metallurgical develops necessary data for raw material requirements after which Standards prepares time and labor information. All this information then is given to Cost for development of figures comparing proposed costs with the current costs. This indicates the effect of the proposed change on factory cost and aids engineering and management decisions on the advisability of the proposed change. Worked into the comparison also are items such as fixed assets, deferred tools, and rearrangement expense.

The Master Mechanic submits an estimate of expenditures for capital equipment, tools, and expense which is added to the above material and labor costs to complete the comparative cost presentation for the new model.

Cost estimates are given the closest possible scrutiny, and they frequently are calculated to the fourth and fifth decimal place. The difference of just two cents per car doesn't sound like very much—

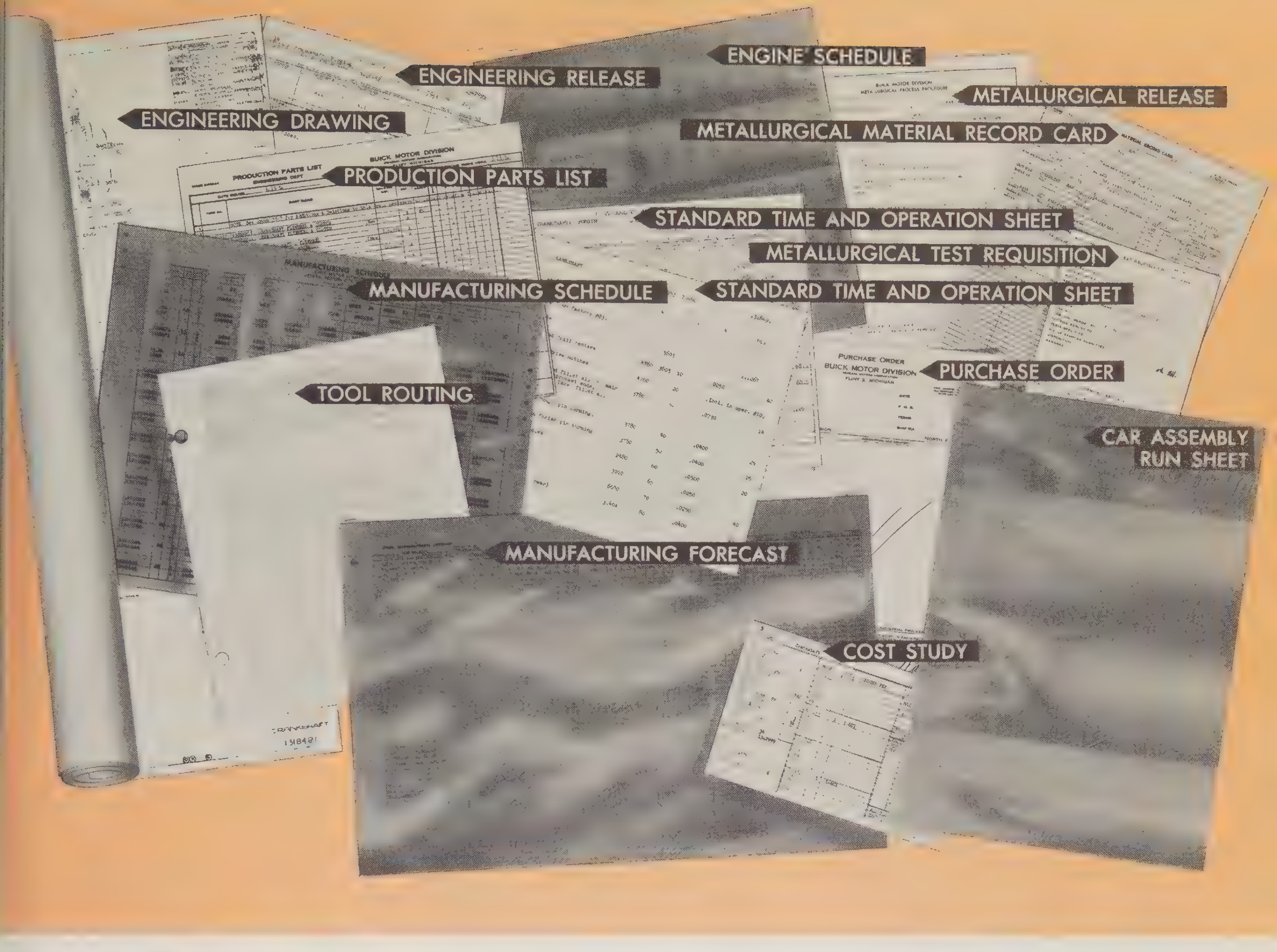


Fig. 1—Releases, routing sheets, drawings, parts lists, are typical of the forms providing information for the orderly control of the vast detail required in production tooling for a new car model.

ut at current production rates, two ents a car may mean $10,000 for the nodel run. So every precaution is taken n preparatory cost estimates to make ertain that the finished model is not riced out of the competitive market, or, n the other hand, that it is not one upon vhich there cannot be a reasonable eturn on investment. Hence the cost ecision has a great bearing upon all roposed changes.

Once the change is approved, howver, the wheels begin to roll. An engieering release for each part required to nake up the new model and a producon parts list are forwarded by Engineerng to Standards. The Cost Department ses the same parts list to set up pricing heets on which material costs and labor osts are recorded and summarized. tandards compiles a routing and disributes copies to all Departments conerned. The Master Mechanic issues ppropriation requests for new nachinery, tools, and rearrangements. Purchasing, Standards, Process, Metallurgical—every Department concerned—all then begin an integrated but closely interwoven effort pointing toward the new model (Fig. 1).

How Departments Function

Taking a closer look at these Departments, assume that a cost estimate is necessary. The project starts in the Standards Department where it is assigned an engineer's estimate number in order to have a permanent record of all potential expenditures for facilities, tools, labor, materials, burden, etc. Working from blueprints and with the Master Mechanic, a decision is reached whether the part is to be made or bought. If it is to be bought, all data are forwarded to Purchasing. After obtaining bids from various sources, these data are passed back to the Cost Department. If the part is to be made, it is determined whether it will be forged, cast, made from sheet stock, bar stock or other material. The Master Mechanic designates which Buick factory or factories will be involved and the estimate tickets and prints are given to all concerned. After the Master Mechanic processes the part and determines what is going to be required, the information is returned to Standards for the labor estimate. The Metallurgical Department surveys the print and supplies Standards with data on material requirements. Since all material used in a fabricated part is purchased, specifications are sent to Purchasing for bids. This information is passed on to Cost.

When all information is assembled, the data are submitted to an estimator in Standards, and if more than one factory is involved each individual factory estimator evaluates the time element. After each operation on the part has been estimated and a time value allocated, the data are gathered in the Central Standards Office and are submitted to Cost where money values are applied to time elements and are computed on a form which shows material costs, labor, facilities, equipment, burden, and tools.

The procedure is only slightly different when a part is released for actual production. The estimate detail is eliminated and the releases go, with blueprints, to all Factories and Departments concerned.

The Master Mechanic begins work on a new model upon receipt of a release from Engineering. After the important "make or buy" decision, and after release by Standards, product engineering prints and production parts lists are received by the Master Mechanic. The Department's Process Division determines whether new machinery is involved and, if so, machine tool vendors are contacted regarding capacity, deliveries, and price. Quotations are requested on standard machines and development work begins on whatever special purpose machines may be required. Studies are started to determine approximate tooling and equipment costs to develop an appropriation request, and orders are placed for equipment and tooling upon approval of the appropriation. Machine order specification forms are developed by Process and go to Plant Layout, to Works Engineering for approval of electrical operating requirements and for obtaining installation costs, and also to the Master Mechanic's Order Department for a general works order and a purchase order. Machine follow-up men are notified and do whatever may be necessary to assure delivery on schedule.

When available, of course, Buick's own machines are put onto new jobs. And simultaneously with placing of orders and moving machinery, work is going forward on tool routings and tool orders for new and additional jigs, fixtures, gauges, and cutting equipment are being placed by the Master Mechanic's Division.

Tool routings, issued by the Master Mechanic, serve as a source of information to assist each Factory and Department to perform its function as required. Typical information contained on this form includes: product part name, number, model year, series, pieces per job, Factory and Department number in which the part is to be produced, operation sequence numbers, machine description and property number, description of operations, listing of all tools, jigs, fixtures, and gauges, together with their tool numbers.

Another Department that has a key role in the bringing out of a new model is Production Control. Production Control has a coordination job. This Department has the responsibility of tying together the operations of the Purchasing and Manufacturing Departments to the end that the cars required by the Sales Department are available on schedule and are built to the specifications developed by Engineering.

Old and New Models Coordinated

Production Control starts work on a new model as soon as the target date for the first cars off the line has been set. Generally speaking its responsibilities fall into two categories: (a) balancing out production of the outgoing model, and (b) planning production requirements of the new product.

As soon as the target date is set and standard and index volume figures are developed, Production Control begins work with Sales to determine the probable requirements of various models, of options, accessories, etc. This information is relayed to various factories in Buick and to outside suppliers to guide them in preparation for new production.

Production Control's next step is to establish three important points: first, the *lead time* necessary for shipment of parts and sub-assemblies to assembly plants; second, time to be required for conversion of dies and tools; and third, time for annual physical inventories.

Next, Production Control cooperates with the Service and Manufacturing Departments to decide upon service requirements on the outgoing model. This is necessary to assure a future supply of service parts. Then orders and delivery schedules are prepared for Purchasing. These cover raw materials as well as purchased parts for completion of the current year's run.

Concurrently with winding up business on the outgoing model, Production Control studies these questions on the new model:

- If parts are purchased, will they be finished or will they require additional work at Buick?
- At what point in the manufacturing cycle will they be required, that is, on the final line, or on the engine, axle, transmission or some other assembl line?
- What lead time will be required f shipment from source to assemb point, what time for inspection, su assembly?
- Will specially engineered containe be required for protection; if so, ho many and who will make them?

These same questions must b answered, in effect, if the parts are to b manufactured at Buick.

Approximately six months before pro duction of the new model is scheduled t start, Production Control forecasts ar prepared estimating the quantities c various models that will be built. Thes are issued periodically as require ments change. From these forecasts, an using lead and float data referred t earlier, purchase orders and shippin schedules are prepared for vendors c purchased parts, and manufacturin schedules are set up for parts to b fabricated.

Production Control maintains a clos follow-up on all these operations and, i event of emergencies such as strikes c difficulties at supplier plants, the De partment is expected to coordinate ac tivities of all manufacturing units maintain the highest possible efficienc

The Metallurgical Department, men tioned previously, plays an early, impor tant role. On parts to be made at Buick Metallurgical consults with the Proces Engineer if heat treating or welding is involved. This is to make sure that equipment and materials capable of meeting specifications are available. In processing a part, Metallurgical establishes bar lengths, sheet or strip widths, surface finish requirements, unit weight, and of course, metallurgical requirements.

For parts furnished by outside sources Metallurgical gives sample parts a most thorough examination. Written disposition is made to the Inspection Department which correlates the metallurgical check with the dimensional check and passes the final disposition along to the Purchasing Department. Particular attention is given to parts coming from a new supplier.

Metallurgical also plays a key role in experimental work, especially where heat treating and welding are involved. One metallurgist is assigned to Engineering

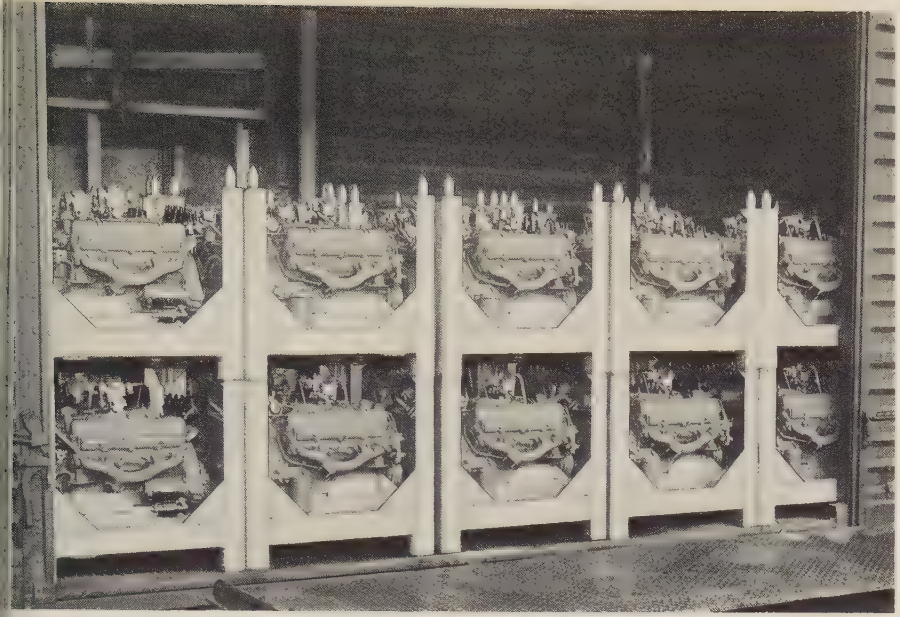


Fig. 2—Railroad cars carry Buick engine assemblies in specially designed skids which protect the engine and allow stacking for compact loading. These skids are furnished by the railroads.

and his job is to see that incoming materials satisfy chemical analysis.

Parts Converge from Vendors

One of the unsung heroes in new model work is the Purchasing Department. The place of a good purchasing staff in the overall picture is often overlooked by people outside of large manufacturing companies.

Initially, Purchasing maintains constant contact with Engineering, relaying to Engineering new or possibly feasible ideas received from the many salesmen and vendors who call.

After blueprints are obtained for parts and specifications for material, buyers in the Purchasing Department begin the job of contacting sources. Buyers, of course, are specialists in their fields, and after they have obtained prices and quotations it is their duty to recommend the best source. Best, it is important to note, doesn't necessarily mean the lowest quotation. In making his recommendation the buyer considers the price, the quality which the source can furnish, the source's known ability to produce and deliver, and its financial responsibility. Frequently the lowest bidder is eliminated because he cannot meet one or more of these requirements. The Director of Purchases makes the final decision on what sources shall be selected. But the responsibility of purchasing does not end there. Monthly releases of requirements are forwarded to suppliers by Purchasing giving a schedule of when parts or material must be shipped. Follow-up men supplement the monthly releases by contact with sources to make sure that schedules are met.

Here is an example of the scope of the Purchasing Department at a plant like Buick. It maintains contact with some 350 producers of production parts and buys some 2,200 different items from them. In addition, of course, there are fabricating materials such as steel, aluminum, pig iron, and many others. And, further in addition to these production items, Purchasing buys various nonproductive items from a total of about 7,500 suppliers.

The Traffic Department, under the Purchasing Department, works in cooperation with follow-up men, tracing material in transit and performing other specific jobs relating to the handling of parts during loading and hauling. At least six months before the model is introduced, Traffic receives from Engineering a contour drawing of the new car, as well as other units such as the engine and the rear axle assembly. These are checked carefully for whatever modifications must be made in the large fleet of rail and highway transportation equipment which carries automobiles and subassemblies. Railroads have specially designed cars, as shown in Fig. 2, for transporting equipment like engines, transmissions, and axles. Any contour changes in these assemblies must be noted months in advance so that the cars may be diverted to home shops and modified. As soon as pilot model assemblies are available, tryouts are made to assure safe production loading and transportation. Traffic also is responsible for intra-plant transportation, which of course is affected in event of a change in manufacturing locations within the plant itself.

That all important factor about a new model—cost—is the major responsibility of the Accounting Department. The complicated job of figuring a reasonable price for the car is only started when material and labor costs are received, as described earlier. Into the price must go such indirect costs as supervision, material handling, inspection, heat, power and light, employe benefits, losses, errors, defects, fixed charges, and many others. Each of these must be factored into cost on the basis of its relation to direct labor, and development of these percentage rates requires exhaustive study through each Factory and Department. When all costs are in, Accounting constructs a price study on the basis of the new model's volume forecast. A list price is established and suggested delivered price is determined for the new model. In a highly competitive industry such as that in which Buick is engaged, any price established must, of course, meet the test of the market place.

Fabrication Problems Solved

Eight Departmental activities, all concerned with preparation for production, have been described so far. They, like all of the others, are pointed toward final assembly—to many people, the popularized, "glamour" phase of the manufacturing business.

To meet the requirements of good assembly practice, production engineers take an early look at the new model program, as in the engine plant, for example. The first thing the engine plant does is to check blueprints of new parts with the current prints, looking for alterations in machining dimensions, in contours, and in projections. This is especially important since so much machining work is required on an engine and, in the case of a change affecting one of the huge transfer machines used in the engine plant, major changes in the machining operations may be necessary (Fig. 3). From the prints it is determined also whether new or altered locating spots will be necessary, whether changes in clamping lugs must be made, and

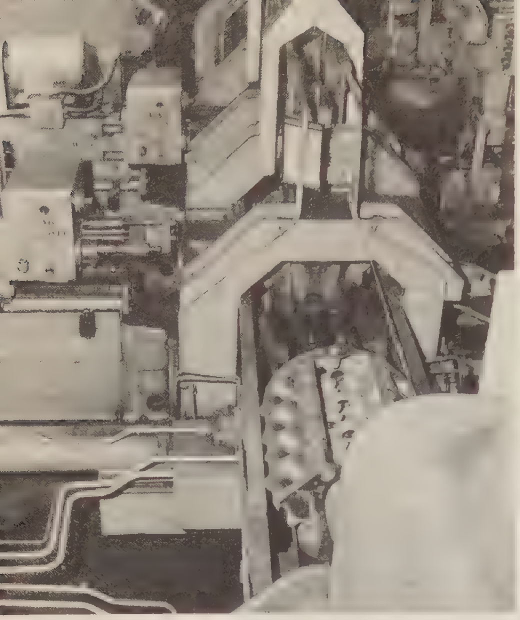


Fig. 3—Eighty-eight holes in the engine block are drilled, reamed, and tapped by a 94-ft-long transfer machine containing 18 working stations. This view of a portion of the machine shows some of the tools and fixtures which would require changes as a result of design changes in the block for a new model. The engine block is positioned on a conveyor at the start of this machine and then is carried automatically through all of the operations without being touched by an operator. Signal lights on a control board call attention to any trouble spots during the operating cycle.

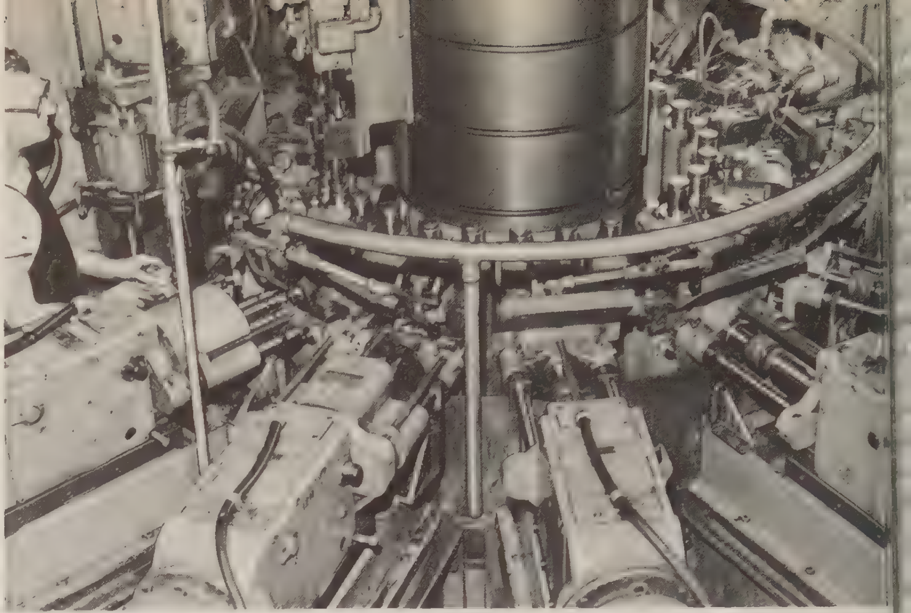


Fig. 4—This 14-station, center column drilli machine at the new Buick engine plant has tools. It drills, chamfers, and taps ten holes in th oil pump cover and it mills both rough and finis cuts on the cover face. Such a machine m require as much as two years for design an construction which is accomplished by clo cooperation between the machine manufactur and Buick.

whether improvements may be made in machine location and in handling.

When a tentative plan and layout for the new job is completed, machinery manufacturers are called in for a discussion of the problems to be solved. Better performance, minimum down time, easier maintenance—all these are considerations. If large multiple heads and fixtures on transfer type machines are involved, decisions are reached on whether entire new heads should be obtained or whether the present heads should be shipped to the manufacturer for reworking, depending on time available for the change. Fig. 4 shows another type of machine used which might entail complex changes. If major relocations are necessary, planning is started on power, lights, water, machine foundations, and similar new requirements. This calls for cooperation between process men, layout men, Works Engineering, and plant foremen.

Any engine change usually affects the engine assembly line; therefore, all fixtures must be checked, as well as all carrying hooks, block test stands, and balancing machines. More than one mile of engine assembly conveyor lines alone must be checked to see that no interferences are created by the new part.

Several thousand shipping skids are used by Buick to convey engines to assembly plants in other parts of the country. Changes in the engine possibly may call for alterations in each skid, as illustrated in Fig 5. Quite frequently engine changes call for completely new assembly methods. These must be worked out so that the line will operate efficiently and smoothly.

The Pattern Shop and Foundry have their problems, too. First, the Pattern Shop receives an experimental drawing from Engineering and from this it is decided how the part will be cast. Wood experimental patterns and core boxes are made and tryout castings are poured. The castings are machined and, if approved by Engineering, a drawing for production is issued.

The next step is to break down the job and make separate drawings for patterns, core boxes, and fixtures. Patterns are designed to fit the molding machines, and drawings are made for various fixtures such as core setting, core loading, grinding, and checking. Wood master patterns then are made for all parts, and metal pattern and core box castings are made from them. Test castings are made, machined, and sent to Inspection for approval before a final okay is given to use the new patterns in production. Frequently, conveyors have to be rerouted; shakeout flasks, core driers, and water test fixtures redesigned; new conveyor hooks and often new shot blasting equipment are required before a useable casting can be produced.

The Sheet Metal Plant, where stamping work is done, has major problem when large die changes are required b a new model. Among these may be th necessity of relocating huge presse which is an expensive operation in ea case.

The supervisors in the Sheet Met Plant work very closely with the Maste Mechanic's Division in the developmen of new dies. Plaster casts are made of th wood models and then set up in variou positions to insure the best possible dra provisions, and to use the smallest siz blank that is feasible. After this i established, the draw dies and all lin dies are ready to be made. Close follow-u is required throughout the die construction period to settle any problems tha arise and to insure maintenance o delivery schedule.

Die tryout is an extremely importan time, for frequently dies just don't function in a production run like they d when only a few experimental jobs are made. The Sheet Metal Plant also is concerned with maintenance of dies for service stampings and with disposition of dies and equipment upon completion of service requirements.

The Forge Shop, too, has an important tryout period. Experimental forgings for ew part are made and then machined d put into assembly. Quite frequently arances or balance will dictate changes d there may be several such changes ore an experimental part is approved.

A tryout run also is held on produc- n dies, which are made by the Forge op. More die changes probably will indicated, for forging in large quan- es often brings out conditions which nnot be uncovered in making samples. ore material may be needed on the t for carburizing, or additional mate- l for clamping while the part is being chined. It's a long process, indeed, m the first forgings to those that ally go into the new model.

"Run Sheet" Guides Final Assembly

The final assembly line, which has to rk right up until the end on the current odel, might be thought of as being one the last to become involved in a new odel. Actually, it is one of the very t. The final assembly people begin rking with the engineering staff even fore final decisions are reached on the w model and before production re- ses are given.

Here are some of the major questions e final assembly plant must solve:

- In what order will parts be put together?
- What sub-assemblies can be made?
- Will a purchased part be painted later or will it be bought painted?
- Will Buick assemble certain parts or assign them for assembly to Fisher Body, which provides Buick's bodies?
- Are present facilities adequate for the new model?
- Is wrench clearance adequate for the new part?

These and many similar problems must e worked out by Assembly in coopera- on with Engineering and the Master echanic. From the answers come deci- ons on conveyor changes, fixture and uge alterations, what pits must be pened or closed, what wrenches and ols must be moved or replaced, and hat physical changes must be made in e assembly building itself.

When sufficient parts have arrived to t up one new model, Assembly runs the r through under simulated assembly ne conditions to check sheet metal and s. Frequently portions of the car are disassembled, then reassembled several times to test various operations and equipment.

As a matter of General Motors policy there is a bare minimum of time between the last car off the line and the first new model production job. The pressure is on the assembly plant at this point. Obviously many alterations cannot be made until the last old model is produced. Then, in a matter of only a few days, everything must be rushed to completion ready for production of the new job. Old equipment is ripped out and new tools are rushed in. Almost overnight the whole line undergoes the transformation necessary for production of the new model. Old materials have to go out, bins must be filled with new stock, men on the line have to be assigned new posts—every detail needs attention. It is a major manufacturing achievement.

The new model finally is ready for production. The materials from the fabricating plants and vendors begin to converge on the final assembly plant where they will emerge into cars ready for shipment to the dealers.

A *run sheet* is made out listing the order in which the models are to be built. This run sheet is distributed to some 90 points in various parts of the Factory to show the order in which the materials are to be placed on the assembly line.

For instance, one run sheet goes to the engine plant where the engines and transmissions are placed on the line. This is to make certain that an engine for the Roadmaster Series gets on a Roadmaster chassis.

Another is sent to the starting point for the chassis line, and another to the head of the body line.

The frame, the engine, the body and front-end assembly, which includes the fenders, all start at different points. Yet they converge on the final assembly line at the right time—otherwise the result might be a green Roadmaster equipped with a Special engine, with yellow front fenders.

The chassis, which includes the engine, frame, wheels, brakes, steering gear, etc., meets the body at the body drop. The work of installing the wiring and instruments in the body has been completed before the body drop operation.

Following the body drop, the front fenders and hood are attached to the car and it progresses to the end of the assembly line where it is capable of running under its own power. After final inspection and any necessary adjustments are performed, the car is ready for shipment.

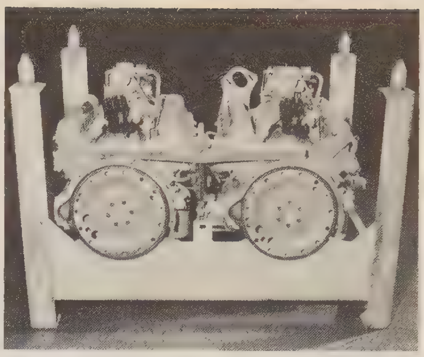


Fig. 5—Shipping skids hold two Buick engine assemblies. New model changes affecting the engine may require alterations to several thousand of these skids.

Summary

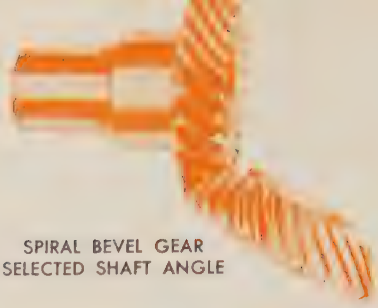
Mass production, it has been said, is attained through standardization and interchangeability. That principle is recognized but is far too general to adequately define mass production as it is thought of in relation to preparation for a new automobile model. To that basic definition of mass production must be added these requirements: (a) accurate machining methods, (b) the orderly progression of product through the factory in a series of planned operations, (c) arrangement of the operations so that the right part arrives in the right place at the right time, (d) mechanical delivery of the parts to their proper places, and (e) a breakdown of each operation into minimum motion.

How well objectives such as those are met depends not only upon the process or manufacturing engineer but also upon the harmonious cooperation of every single Department.

This conclusion, then, may be drawn from the production story: the task of building cars does not stem from the genius of one man nor any group of men. It is the result of close teamwork between many groups with a wide diversity of talents. The general manufacturing manager's team, the comptroller's team, the purchasing team, and a dozen others, all contribute their share of knowledge to the success of this business. All of them are working toward a common goal—to make better cars and to make them at a price which the greatest number of people can afford.

STRAIGHT TOOTH GEAR
AND RACK

STRAIGHT TOOTH SPUR GEARS



SPIRAL BEVEL GEAR
SELECTED SHAFT ANGLE

HELICAL GEARS

SPIRAL GEARS
SELECTED SHAFT ANGLE

HERRINGBONE GEARS

HELICAL PINION AND INTERNAL GEAR

STRAIGHT TOOTH BEVEL
90° ANGLE

HOURGLASS WORM AND WHEEL

SPIRAL GEARS
90° SHAFT ANGLE

WORM AND WHEEL

STRAIGHT TOOTH BEVEL
SELECTED SHAFT ANGL

TYPICAL AUTOMOTIVE HYPOID GEAR

AUTOMOTIVE TYPE SPIRAL BEVEL GEAR – 90° SHAFT ANGLE

UNUSUAL MITER HYPOID

Gear Wheels and Applied Mathematics

By **BAIN GRIFFITH**
Chevrolet Motor
Division

Modern gear design simplified by strict mathematical pattern

The universal application of gears, with their variety of tooth forms, differences in material and in manufacturing accuracy, is familiar to everyone. An understanding of gears, however, is not similarly widespread, even among many technical people. Whether the gear does its job satisfactorily in a finished product depends largely upon the engineering design of the gear. The development of gears which can be manufactured economically is usually a complicated process. Yet the approach is profoundly simple because the basic tool of the experienced gear engineer is mathematics, patiently and properly applied. A review of some of the gear design fundamentals demonstrates how engineers developed a time-saving formula which solves the design and specifies the machine settings to manufacture a set of hypoid gears. Without such a formula, a year of mathematical work would be necessary using normal schoolroom procedure.

EVERYONE remembers the first watch he was given as a youngster. The gift invariably carried with it the admonition: "Don't drop it; don't lose it, and don't take off the back of the case." But just as invariably he ran and hid and promptly took off the back and there inside were a number of little gears quietly working. The younger the child, the more fascinating was the gear train, and perhaps he never ceased to be interested in their hypnotizing motion.

Doubtless some have learned, perhaps unconsciously through a first association with a watch, to respect and even admire gear wheels. The sole purpose of a gear is to put power in a wheel in the way in which it is wanted. For their purpose, the gears in a watch do a most satisfactory job since they operate at a relatively slow speed. The gear that drives the second hand, for example, turns completely only once a minute. Refinement of gear tooth shape or profile, as it is generally termed, is critical in a watch only in reducing friction to a minimum.

Now in contrast to a slow moving mechanism like a watch, consider an air turbine no larger than a small handbag in which the turbine wheel and shaft and the first gear in the train operate at a speed of 84,000 rpm. Fortunately, gears of this type, because of their larger size, can be manufactured to the most exacting accuracy. Such gears do not have to carry a heavy tooth load. Rather, the power developed is a function of a relatively light tangential load and a very high speed.

Fig. 2—(Left) A collection of typical gears illustrating a variety of designs which are the result of a need to perform in an unusual way or to be easily made.

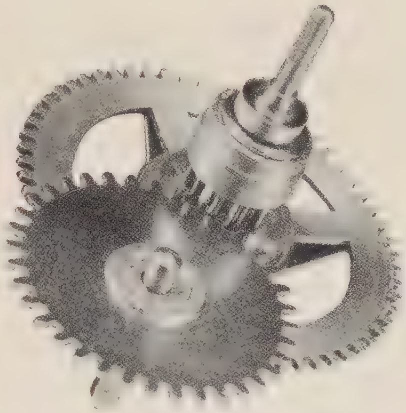


Fig. 1—A lantern pinion and gear typical of those used in inexpensive modern clocks.

Modern manufacturing methods have made possible refinements of tooth form in small gears which make them vastly superior to the lantern gears common to the old-fashioned kitchen clock. Hundreds of years old, the lantern gear was the first workable concept of the small gear. It was made of hardwood pins and worked quite well as a spur gear pinion driving a larger wheel with pegs sometimes called cogs. The lantern gears of an inexpensive clock, as shown in Fig. 1, are usually made of steel pins fixed in brass end plates about as big around as a lead pencil. This is not a difficult construction and the gears can be made to any desired degree of accuracy.

This gear train has one drawback, however, which makes it useless in machinery requiring any degree of speed or tooth load in its function. Unless the mating gear is designed and manufactured with the most painstaking care and the center distance of the two shafts is maintained with equal accuracy, a constant change in angular velocity from one gear to the other results.

Recall the disproportionate noise which issued forth when a tightly wound toy clockwork locomotive was allowed to run, in the hand perhaps, without resistance. Noise in itself is not necessarily objectionable but it portends errors which shorten the trouble-free life of the gear. This almost ear-splitting buzz was the result of tooth interference and torsional vibration from lantern gears and cog wheels just running too fast. Common sense suggests the impossibility of a gear of this type running 84,000 rpm.

If gears do not have universal appeal, they certainly have universal application—from the small wrist watch to the enormous multiple-faced herringbone gears which drive the screws of a battleship. The style and size of gears range within and even beyond these limits. Of course, they differ in engineering design, in manufacturing accuracy, and widely in materials—from nylon to carburized steel. Their only requirement is their adequacy for the finished product (Fig 2).

The plant manager at Chevrolet's Gear and Axle Plant operates the largest gear manufacturing establishment of its

Fig. 3—The center-to-center distance of the pulleys is divided at the intersection of the crossed belt in direct proportion to the size of the pulleys. In gear parlance this dividing point is called the pitch point.

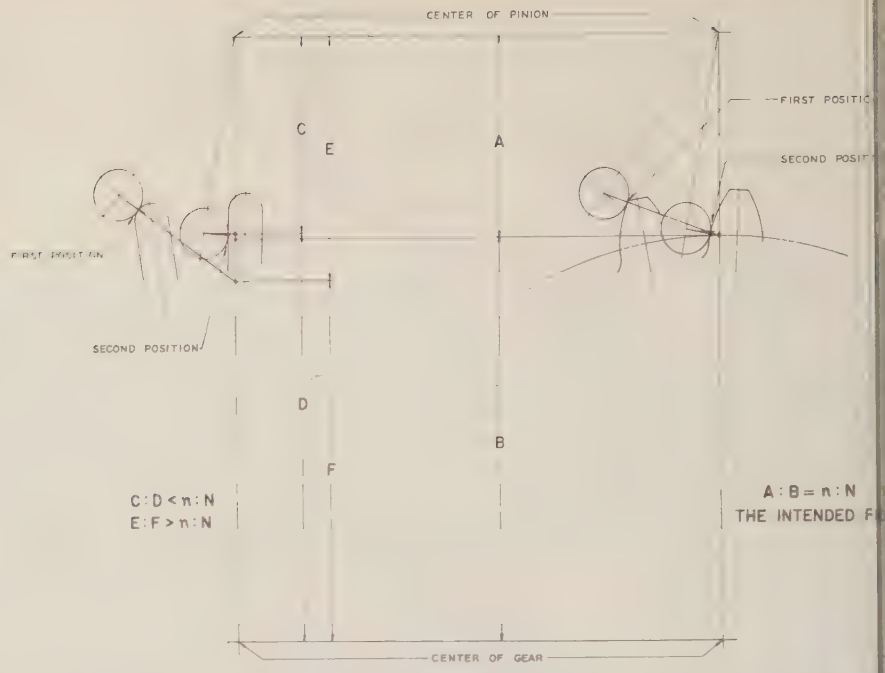


Fig. 4—Tooth engagement of a lantern pinion with a cog wheel, shown on the left, illustrates how t common normals divide the center-to-center distance in varying ratios, resulting in a change in angul velocity. Tooth engagement of a lantern pinion with the conjugate gear, shown on the right, illustrat how the center-to-center distance always is divided in a constant ratio.

kind in the world. He has remarked many times, in the more than 40 years he has been in the business, that 90 per cent of the quality of a gear is contributed by engineering design and only 10 per cent by manufacturing accuracy. A substantial burden of the success of the product, therefore, must rest upon the engineer.

Gear engineers are an esoteric cult whose members worship with the greatest devotion at the shrine of mathematics. They obtain, and have learned to expect, little or no sympathy simply because of the absence of an interest in mathematics—a characteristic of entirely too many people. As the philosopher said, "We fear only that which we do not understand." Gears are not sufficiently well understood even among all technical people, for some do not have the mathematical interest necessary to recognize the problem's simplicity. Actually, gear designing is profoundly simple because it follows a rigorously definite, precise, exacting, understandable, and predictable mathematical pattern. The basic engineering tool in gear development and design is simply mathematics, patiently and properly applied, plus an adequate background of experience.

Familiar Gear Types

Now for a quick acquaintance with the field, review the selected collection of a gear engineer's accomplishments which are typical of only the most exacting and finest gears made. The collection shown in Fig. 2 is small and might include a multitude of special designs, all interesting, but compromised in a number of ways to make them cheaper to manufacture or adaptable in some unusual fashion.

The use of the mathematics related to gear design is limited herein first to the most elementary discussion of the quality that separates the gears from the cog wheels and, second, to the impossible—hyperboloid pitch surfaces. Every other gear design problem lies in between these limits and the problems are legion.

The purpose of a set of gears is to transfer motion uniformly and the set's quality is determined by its deviation, even though infinitesimal, from ideal uniformity of motion. A gear transfers motion uniformly; a cog wheel does not.

A great many gear tooth forms have been designed in attempts to eliminate the lack of uniformity evident in the cog wheel. Except for a few specialized purposes, in watches and clocks for example, only one form, the circular involute form, is of any importance today.

A schematic illustration of the action of meshed gears is a pair of pulleys transmitting motion from one to the other through a crossed belt as in Fig. 3. If the belt were made of rubber and the center distance were changed, it is evident, by common sense or simple geometry, that the center-to-center distance of the pulleys is divided at the intersection of the crossed belt in direct proportion to the diameter of the pulleys. Since the number of teeth is a function of the diamete the center-to-center distance between two gears of a pair is divided at the pit point (which is equivalent to the po of belt intersection) in direct proporti to the number of teeth in the gears. transmit motion uniformly, the teeth a pair of gears must have their comm normals pass through the pitch point every phase of tooth engagement. A deviation whatsoever produces acceler tion or deceleration in the driven gea

Now note what happens to a lante gear and cog wheel. Fig. 4 is a grotesqu exaggeration but it clearly shows ho the relative velocity of the driven memb must change through the period of toot engagement. The common normals the point of mesh divide the center-t center distance of the gears in eve varying ratios. In the first position, th normal divides the center-to-center di tance in the proportion *E* to *F* which greater than the proportion of the number of teeth. In the second position, th normal divides the center-to-center dis tance in the proportion *C* to *D* which less than the proportion of the number teeth. The ratios at any phase of mes are actually the instantaneous ratio the gear set. However, the lantern gea can drive a cog wheel tooth of mor unusual shape, which is illustrated o the right in Fig. 4, at a uniform speed

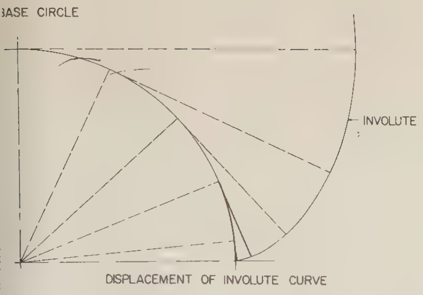


Fig. 5—The displacement of an involute curve—any normal to a circular involute is tangent to the base circle.

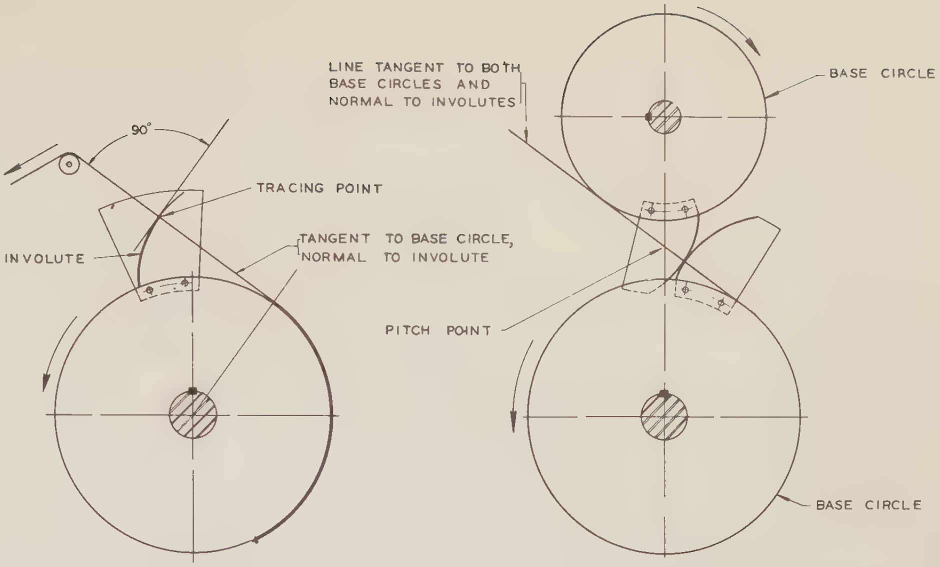

90°
TRACING POINT
INVOLUTE
TANGENT TO BASE CIRCLE, NORMAL TO INVOLUTE
LINE TANGENT TO BOTH BASE CIRCLES AND NORMAL TO INVOLUTES
BASE CIRCLE
PITCH POINT
BASE CIRCLE

Fig. 6—An involute curve (left) is traced on the card attached to the rolling disc showing the tangent to the base circle normal to the involute. The two cards cut out to form involute templates (right) transmit uniform motion from the lower to the upper shaft. A line tangent to both base circles is normal to the involute.

At every phase of engagement, the common normal passes through the pitch point and divides the center-to-center distance of the gears in direct proportion to the number of teeth in the gears. To graphically or analytically develop this unusual form is time consuming and most difficult of accurate reproduction.

Advantages of the Involute Form

The kinematic requirement for transmitting motion at a uniform velocity is fulfilled when the common normals to the point of tooth engagement are tangent to the base circles of the gears. Fig. 5 illustrates the fact that any normal to a circular involute is tangent to the base circle. Therefore, accurately developed involute form teeth fill the exacting kinematic requirement necessary to obtain uniform velocity from one gear to the other. All that is required is maintaining the centers of the base circles and very perfect involutes. This is described, or recognized, as smooth, perfect rolling action. The common normals to the involute teeth in Fig. 6 readily pass through the pitch point with no deviation in direction; the direction follows perfectly the path of the schematic crossed belt. This condition is coincident with the involute form but is of no consequence in transmitting uniform action.

Equal in importance to the kinematic advantages of the involute tooth form is the manufacturing advantage in being able to design machinery and tools to develop this tooth shape accurately, or to generate the gear as the term is understood. Returning to the basic concept of the circular involute, the radius vector at any point on the curve from the base circle is necessarily equal to the distance from the start of the involute, around the periphery of the base circle, to the point of tangency of the selected radius vector. Now, if the grinding wheel in Fig. 7 is adjusted with its cutting face normal to a plane and the base circle is rolled, without slipping, across the plane, a perfect circular involute can be developed to any degree of refinement required. This is the sole principle involved in generating gear teeth of involute form.

The manner in which this principle is applied in most commercial gear cutting machines is to set the tool at the pressure angle of the tooth and roll the gear on a correspondingly larger circle. The geometric aspect of this is evident in Fig. 8. Involute tooth shapes are loosely described in terms of the pressure angle which is all important in successful design of the cutting tool. But the cutting or generating tool—at any angle—is a flat, straight plane, easily made, which contributes immeasurably to the commercial success of the involute tooth form.

Any required degree of refinement towards perfect action is obtained in just one tooth. A large, undressed cast steel gear is suitable to drive a stone crusher. A delicate chronometer may require an almost microscopic gear cut with a sapphire fly cutter whose form is obtained with diamond dust and a lapidary wheel under a microscope. But fundamental refinement of the tooth form dictates the quality of the gear—in turn dictated by its design and intended purpose—and the required quality generally dictates the most suitable method by which it is obtained.

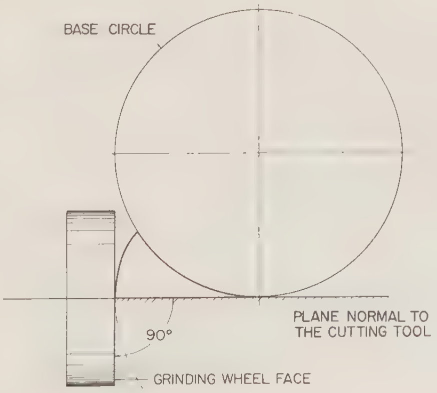


Fig. 7—The generating tool cuts a perfect circular involute when the base circle is rolled on the plane normal to the grinding wheel face.

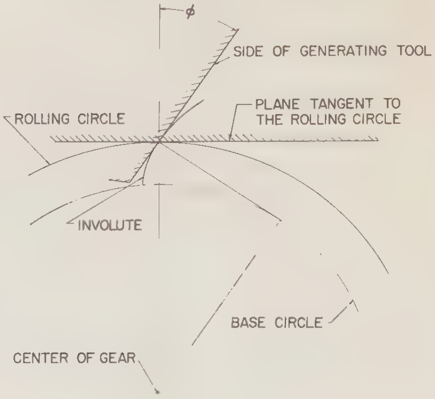


Fig. 8—The generating tool cuts a perfect circular involute when the tool side is cocked at an angle to the tangent plane of a rolling circle and the gear is rolled across that tangent plane.

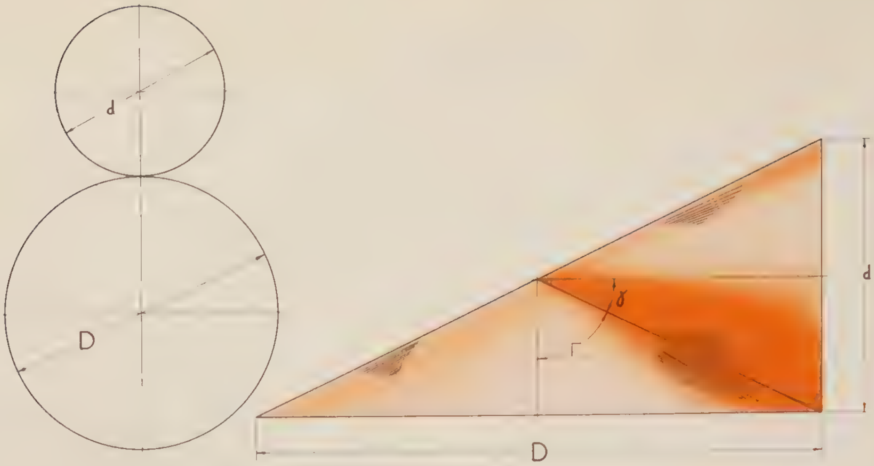


Fig. 9—The pitch surfaces of spur gears are cylinders, shown on the left. The pitch surfaces of bevel gears are cones (right). The number of teeth is directly proportional to the diameters, as $n/N = d/D$.

The Pitch Surface

All pitch surfaces are abstractions. Hyperboloidal pitch surfaces are perhaps the most difficult to visualize. The pitch surface of a gear (Fig. 9) is that invisible geometric shape in every style of gear through which action passes as pure rolling motion without slipping. This is the framework around which the teeth are designed. Spur gears are a simple example: the pitch surfaces are two invisible cylinders both tangent at the pitch point and their diameters are proportional to the number of teeth in the two gears. Almost as simple are the pitch surfaces in a pair of bevel gears. Obviously, the surfaces in this case are cones with common elements tangent and containing the pitch point. The cone points are coincident because the shaft centers intersect. The tangent of either cone angle is immediately recognized as the appropriate ratio of the number of teeth in the mating gears. Suppose it is required that the shaft centers do *not* intersect, as in Fig. 10. In this case the shafts are merely offset the desired distance, resulting in gears with hyperboloidal pitch surfaces.

Ordinarily, one thinks of a hyperboloid as a surface of revolution developed by revolving a hyperbola around any properly selected polar axis. Now, imagine the hyperboloidal pitch surfaces of gears to be something more concrete and developed from a straight line.

Look at it this way. The cylinder, coaxial cones, and a hyperboloid in Fig. 11 are a family of geometric figures. Their only difference is the relation of the generating line to the axis of rotation. In the illustration, the generating straight line is shown in color and the generated surface is described by the black lines. If the generating line is parallel to the axis and revolved in a circle about the axis, a cylinder is generated. If the generating line intersects the axis and is rotated about the same circles which limited the cylinder, two symmetrical coaxial cones are generated. Finally, if the generating straight line is not parallel to and does not intersect the axis and is rotated about the same circles which limited the cylinder and the cones, a hyperboloid is generated.

The conditions which govern the generation of these surfaces are the conditions which govern their use as pitch surfaces. Spur gears have parallel axes, bevel gears have intersecting axes, and hyperboloidal gears have non-parallel and non-intersecting axes.

The difficulty of accepting the geometric fact that a straight line can be laid tangent across the warped surface of a hyperboloid is due to a lack of familiarity with hyperboloids. Taki advantage of this fact immediately, t hyperboloids can be tangent to ea other with perfect geometric accura as in the illustration in Fig. 12 of t conjugate hyperboloids which have common element. They will, therefo roll around one another, accepting little endwise sliding, just as two cyli ders or two cones roll around one anoth Endwise sliding is characteristic of hyperboloidal gears and is the ba reason for using extreme pressure lub cants for rear axle gears.

In this way, perfect geometric shap are developed for the pitch surfaces hyperboloidal gears. Substitute suitab designed teeth for these abstract e ments on the cylinders, the cones, a the hyperboloids, and perfect conjuga gears of the three general types a created.

It is evident that the direction of t hyperboloid element is not to be imm diately nor easily recognized. This is cause for uneasiness for the considerati of the hyperboloids of pitch surfaces highly theoretical and they never appe in the actual design and development the gears themselves. Recognizing fact, the term *hypoid* will hereafter used in describing gears derived fro hyperboloid surfaces. The shorter te is merely a contraction coined ma years ago and properly belongs to Gleason Works which makes the machi tools for commercial manufacture of th type gear.

The pitch surfaces that are actua designed, and to which the tooth desi is adjusted, are cones which are pr sumed to be properly tangent to the

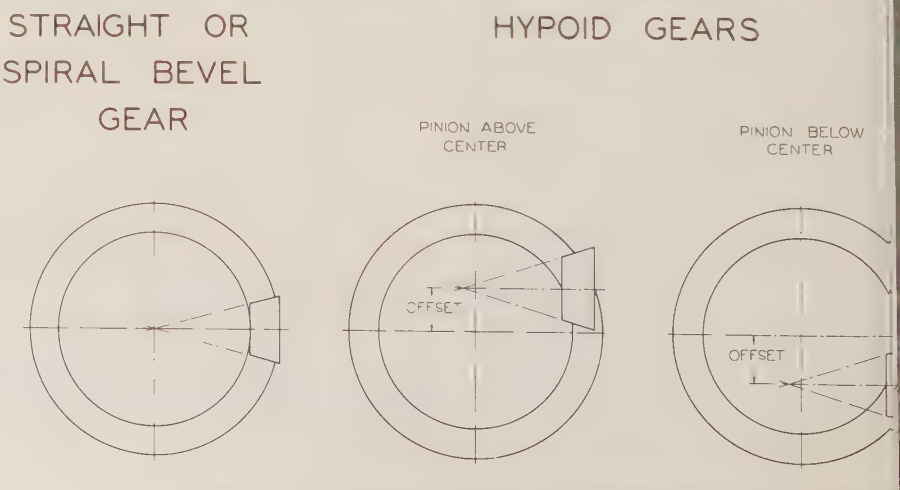


Fig. 10—Schematic diagram of straight or spi bevel gear and hypoid gears showing n intersecting shaft centers.

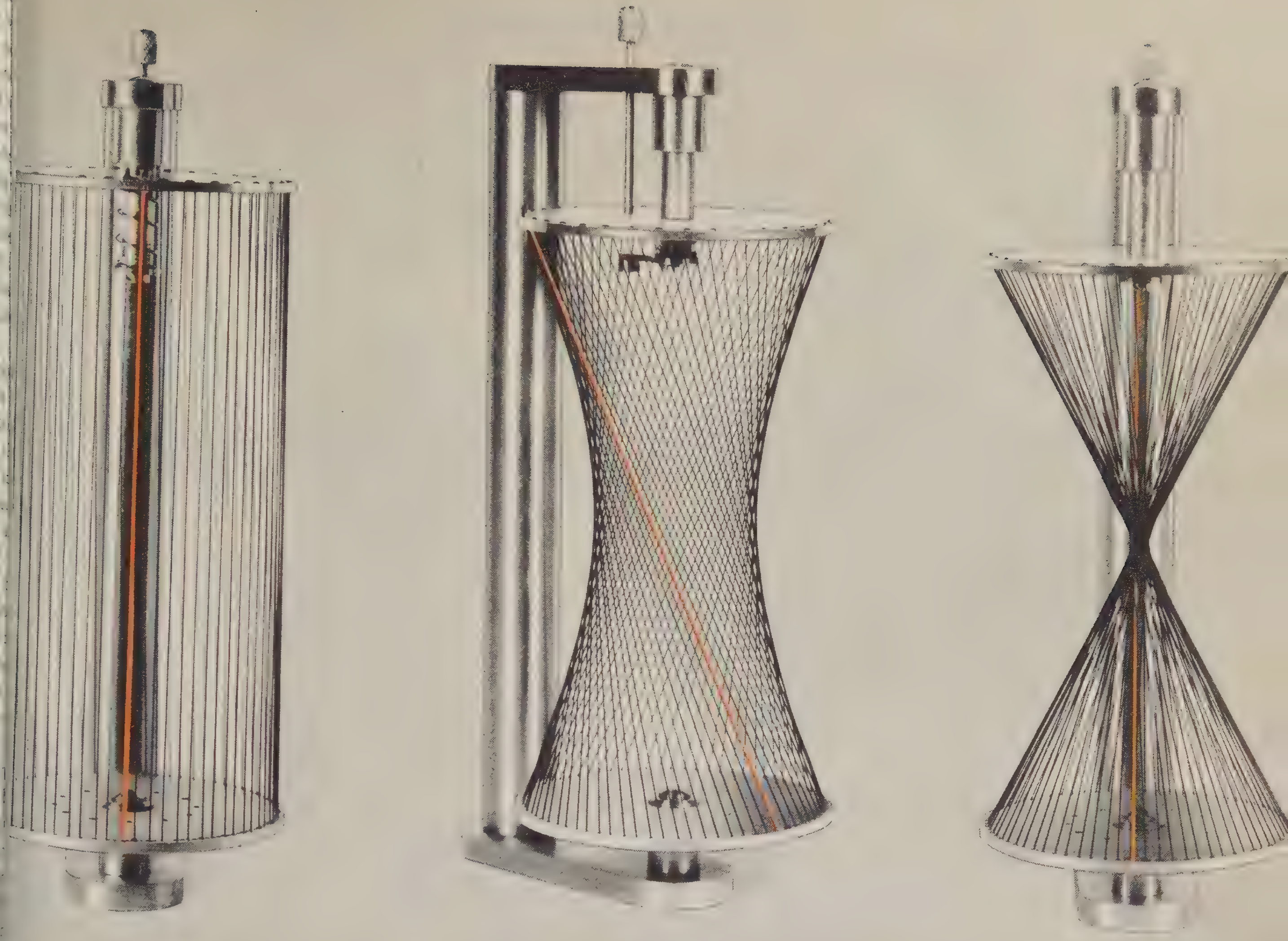
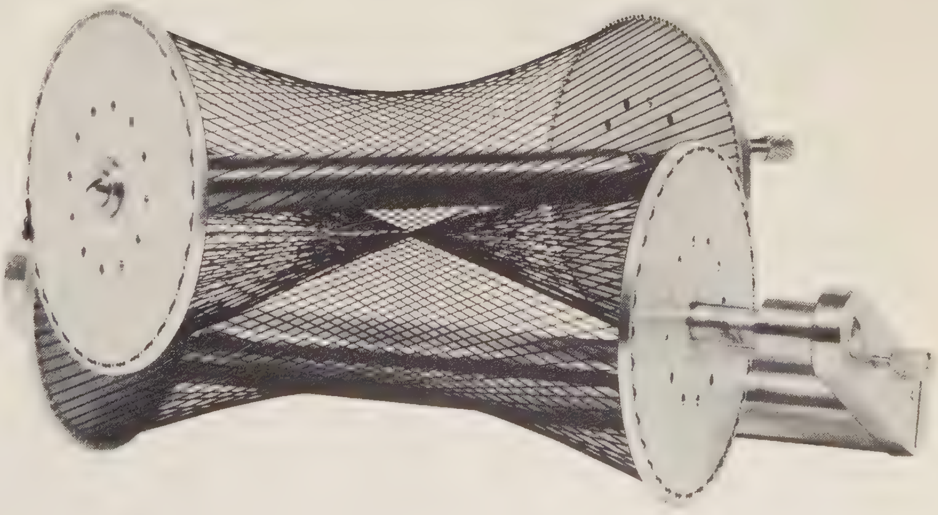
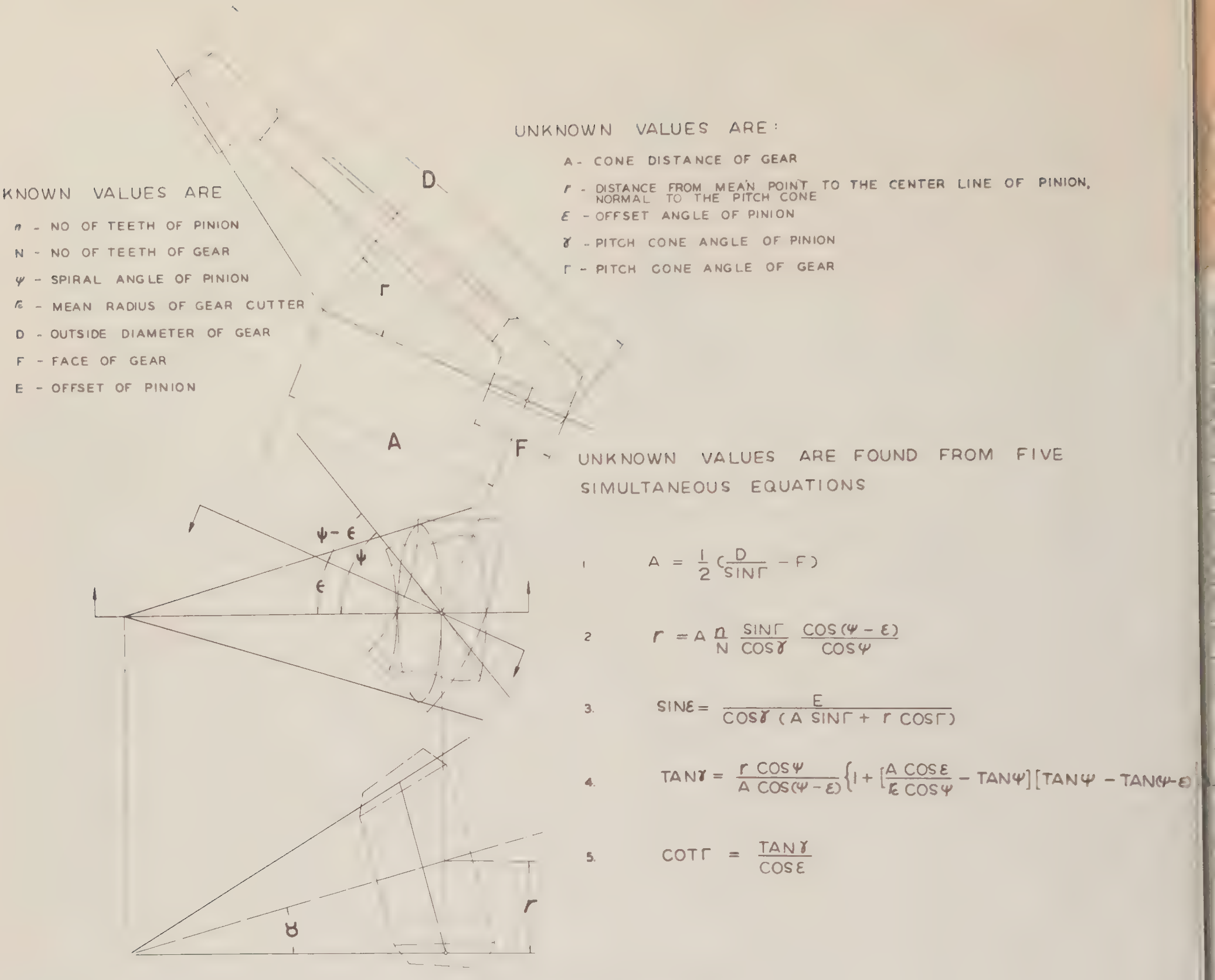


Fig. 11—A family of geometric figures—the position of the generating line determines the resulting figure. A hyperboloid is a surface of revolution developed by rotating about an axis a straight line which neither parallels nor intersects the axis.

Fig. 12—Two hyperboloids in perfect conjunction have a common straight line element and, therefore, will roll around one another.





KNOWN VALUES ARE

n - NO OF TEETH OF PINION
N - NO OF TEETH OF GEAR
ψ - SPIRAL ANGLE OF PINION
r_c - MEAN RADIUS OF GEAR CUTTER
D - OUTSIDE DIAMETER OF GEAR
F - FACE OF GEAR
E - OFFSET OF PINION

UNKNOWN VALUES ARE:

A - CONE DISTANCE OF GEAR
r - DISTANCE FROM MEAN POINT TO THE CENTER LINE OF PINION, NORMAL TO THE PITCH CONE
ε - OFFSET ANGLE OF PINION
γ - PITCH CONE ANGLE OF PINION
Γ - PITCH CONE ANGLE OF GEAR

UNKNOWN VALUES ARE FOUND FROM FIVE SIMULTANEOUS EQUATIONS

1 $$A = \frac{1}{2}\left(\frac{D}{\mathrm{SIN}\,\Gamma} - F\right)$$

2 $$r = A\,\frac{n}{N}\,\frac{\mathrm{SIN}\,\Gamma}{\mathrm{COS}\,\gamma}\,\frac{\mathrm{COS}(\psi-\varepsilon)}{\mathrm{COS}\,\psi}$$

3. $$\mathrm{SIN}\,\varepsilon = \frac{E}{\mathrm{COS}\,\gamma\,(A\,\mathrm{SIN}\,\Gamma + r\,\mathrm{COS}\,\Gamma)}$$

4. $$\mathrm{TAN}\,\gamma = \frac{r\,\mathrm{COS}\,\psi}{A\,\mathrm{COS}(\psi-\varepsilon)}\left\{1 + \left[\frac{A\,\mathrm{COS}\,\varepsilon}{r_c\,\mathrm{COS}\,\psi} - \mathrm{TAN}\,\psi\right]\left[\mathrm{TAN}\,\psi - \mathrm{TAN}(\psi-\varepsilon)\right.\right.$$

5. $$\mathrm{COT}\,\Gamma = \frac{\mathrm{TAN}\,\gamma}{\mathrm{COS}\,\varepsilon}$$

Fig. 13—Formula for a hypoid gear set.

hypothetical hyperboloids. Now, of course, tangent cones whose axes are not coplanar can be tangent at only an infinitesimal point and this will be the middle of the gear tooth across the face. But the formula for the size and proportion of these cones is quite another matter.

From Theory, a Practical Formula

The formulae to be described were developed 17 years ago when Charles W. Jackman, now an assistant staff engineer at Chevrolet Motor Division, made an analysis of hypoid gears from a paper written at the Gleason Works. He first stated the problem in 13 equations with 13 unknown quantities which he showed to the writer. Working together, Mr. Jackman and the writer equated and interchanged them until they resolved the problem into the five equations shown in Fig. 13.

Five answers are required to five places of the decimal and the nearest minute of the arc. However formidable five simultaneous equations of trigonometric form may appear, their solution is absolutely imperative. They must be solved in order to get into the really useful business that follows: designing teeth for the surfaces, designing gear blanks to properly contain the teeth, and calculating the settings for the five different machines which are necessary to cut the teeth.

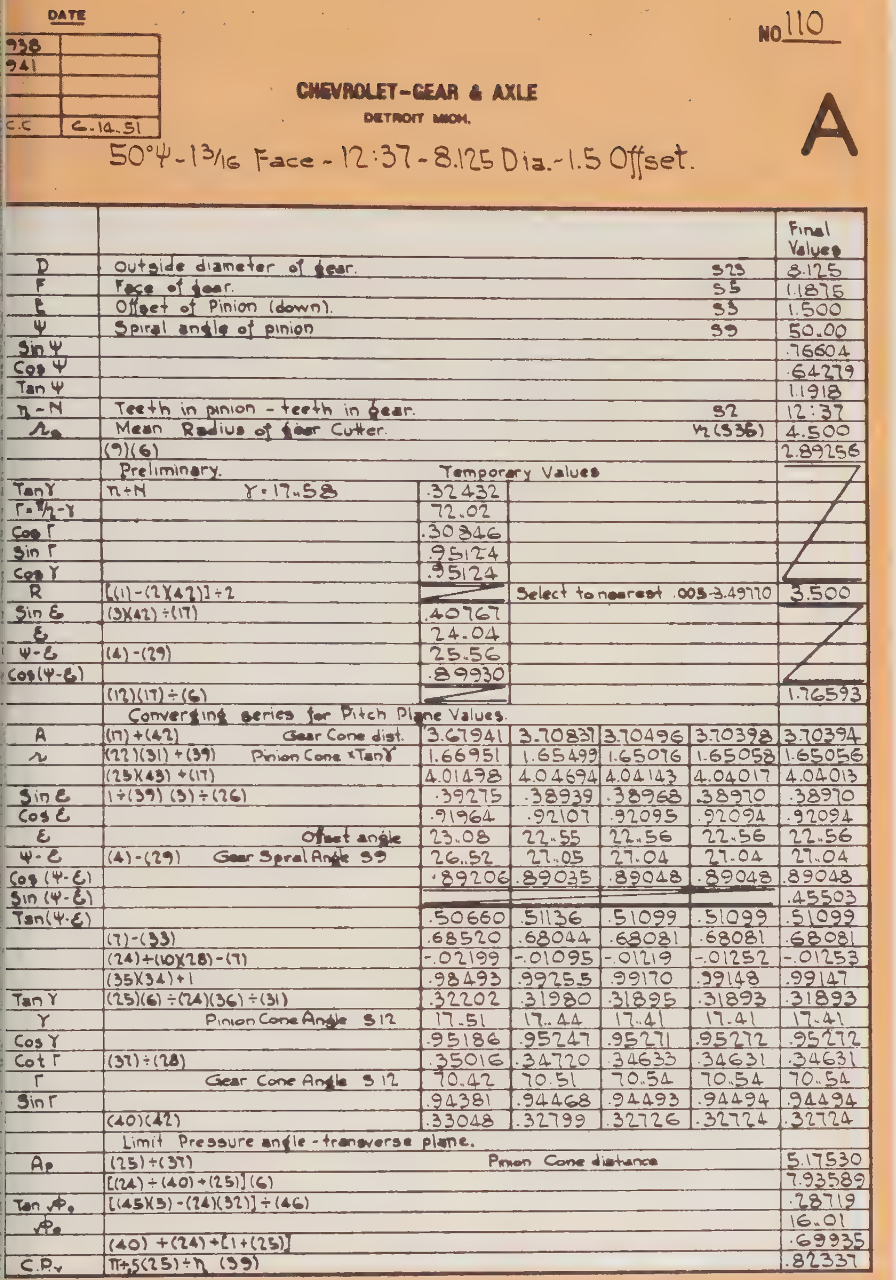
With sufficient knowledge of trigonometry to interpret a table of functions, the required answer may be obtained in about 30 minutes. In the solution of the problem, at least a fair approximation of some of the answers are known and the others can be determined by the method of specific iteration. The procedure is quite simple and requires only some place to start. Since the cone angle of the smaller gear resembles in principl as well as function the cone angle o any normal set of bevel gears, the tangen of the cone angle approaches the rati of the number of teeth. This operatio is listed as item 12 in Fig. 14 and from it items 43, 42, and 39 are derived and noted on the three lines below line 13.

Similarly derived are approximation of items 29, 30, and 31 which are noted on the three lines below line 18. Values are calculated from these approximations for items 24 to 43, inclusive. Note that new values for the approximated terms result from these calculations and appear in their proper sequential position. In the next trial calculation, the process is repeated using the calculated values from the first calculation as approximate values in the second calculation. Reading across the five trial columns, note how rapidly items 24, 25, 29, 38, and 41, the crucial unknowns, approach a definitely converging relationship.

The standard form is set up to accommodate five sets of computations. Some gear set proportions establish definite values, within the limits of accuracy required, in less than five applications of the computation.

To appreciate more fully the importance of getting on with the task there are, besides the page shown, eight more pages with about 600 computations plus three simpler pages required to complete the solution of the design and specify the machine settings to manufacture a set of hypoid gears.

The problem presented is certainly most difficult if a solution is attempted using normal classroom procedure. If hypoid gears had to be designed and the astounding amount of computation carried through in familiar fashion, it would probably take a year of steady mathematical work. It is of economic necessity that methods such as this be developed and exploited to their fullest to make such designs feasible.



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NO 110

CHEVROLET-GEAR & AXLE
DETROIT MICH.

A

50°ψ-13/16 Face-12:37-8.125 Dia.-1.5 Offset.

							Final Values
D	Outside diameter of gear.	S23					8.125
F	Face of gear.	S5					1.1875
E	Offset of Pinion (down).	S3					1.500
ψ	Spiral angle of pinion	S9					50.00
Sin ψ							.76604
Cos ψ							.64279
Tan ψ							1.1918
n - N	Teeth in pinion - teeth in gear.	S2					12:37
r_o	Mean Radius of gear Cutter.	½(S36)					4.500
	(9)(6)						2.89256
	Preliminary.		Temporary Values				
Tan γ	n÷N	γ = 17.58	.32432				
$\Gamma = \pi/2 - \gamma$			72.02				
Cos Γ			.30846				
Sin Γ			.95124				
Cos γ			.95124				
R	[(1)-(2)(42)]÷2			Select to nearest .005-3.49770			3.500
Sin ε	(3)(42)÷(17)		.40767				
ε			24.04				
$\psi-\varepsilon$	(4)-(29)		25.56				
Cos$(\psi-\varepsilon)$			.89930				
	(12)(17)÷(6)						1.76593
	Converging series for Pitch Plane Values.						
A	(17)+(42)	Gear Cone dist.	3.67941	3.70831	3.70496	3.70398	3.70394
r	(22)(31)+(39)	Pinion Cone × Tan γ	1.66951	1.65499	1.65076	1.65058	1.65056
	(25)(43)+(17)		4.01498	4.04694	4.04143	4.04017	4.04013
Sin ε	1÷(39) (3)÷(26)		.39275	.38939	.38968	.38970	.38970
Cos ε			.91964	.92107	.92095	.92094	.92094
ε		Offset angle	23.08	22.55	22.56	22.56	22.56
$\psi-\varepsilon$	(4)-(29)	Gear Spiral Angle S9	26.52	27.05	27.04	27.04	27.04
Cos$(\psi-\varepsilon)$			.89206	.89035	.89048	.89048	.89048
Sin$(\psi-\varepsilon)$							.45503
Tan$(\psi-\varepsilon)$			.50660	.51136	.51099	.51099	.51099
	(7)-(33)		.68520	.68044	.68081	.68081	.68081
	(24)÷(10)(28)-(7)		-.02199	-.01095	-.01219	-.01252	-.01253
	(35)(34)+1		.98493	.99255	.99170	.99148	.99147
Tan γ	(25)(6)÷(24)(36)÷(31)		.32202	.31980	.31895	.31893	.31893
γ		Pinion Cone Angle S12	17.51	17.44	17.41	17.41	17.41
Cos γ			.95186	.95247	.95271	.95272	.95272
Cot Γ	(37)÷(28)		.35016	.34720	.34633	.34631	.34631
Γ		Gear Cone Angle S12	70.42	70.51	70.54	70.54	70.54
Sin Γ			.94381	.94468	.94493	.94494	.94494
	(40)(42)		.33048	.32799	.32726	.32724	.32724
	Limit Pressure angle - transverse plane.						
A_p	(25)÷(37)	Pinion Cone distance					5.17530
	[(24)÷(40)+(25)](6)						7.93589
Tan ϕ_o	[(45)(3)-(24)(32)]÷(46)						.28719
ϕ_o							16.01
	(40)+(24)+[1+(25)]						.69935
C.P.$_v$	π÷5(25)÷n (39)						.82337

TE: The formulae in Fig. 13 are coded on this work sheet. The computation scheme is adjusted quential operations on a typical calculating machine.

mple: Item 37 is (25) (6) ÷ (24) (36) ÷ (31), and means to perform each operation in ence with the indicated item; algebraically, it means (25) (6) (36) / (24) (31). The final ver in the calculator is entered in its appropriate space on the work sheet.

Fig. 14—Solution of five simultaneous equations by specific iteration. Reading across the five trial columns, the crucial unknowns, items 29, 30, 31, 39, 42, and 43, approach a definitely converging relationship.

Summary

In a highly competitive market an assembled product is for sale in terms of *quality* versus *price*.

The commercial success of *mass production* is *mass assembly*. Rarely does one want a pair of gears, but probably everyone wants a quality automobile at a fair price. The cost of a product is very largely a function of the time—man-hours—expended in making the parts and putting them together. Time spent in backtracking, disassembly, and rebuilding is money wasted. And gears are especially temperamental; they must be precisely identical within discouragingly close dimensional tolerances to permit random assembly and ultimate acceptance within the high standard of required quality. The required quality is compatibility with the shiny steel box full of silence sold to the typical American as an automobile. Engines are silenced with mufflers; wheels are silenced with rubber, but gears can only be silenced with quality.

Fine gear designs may be diligently refined in the crucible of mathematics, but fine gears are only created by artisans with patience and devotion to their task.

Air Suspension Ride: How Engineers Gave Resilience to a Compressed Air System with Rubber Bellows

By HAROLD E. FOX and
DONALD J. LA BELLE
GMC Truck and
Coach Division

Exertionless riding must be as natural as walking

Almost since development of the first successful gasoline car in America, in 1892, engineers have been concerned with suspension systems and their effects on the driver and passengers. The conventional steel spring suspension was developed and, today, remains the mainstay in assuring passenger comfort. While improvements continue on steel spring suspension, engineers have been studying the use of compressed air, controlled by some means which would offer resilience for the suspended body, as a suspension medium. They have studied the use of compressed air for suspension of vehicle bodies for more than 12 years, and GMC Truck and Coach Division engineers have developed a successful system now in use on some 1953 coach models.

During the past 60 years, motor vehicles have evolved from awkward, buggy-like conveyances to safe, dependable, and efficient machines. Yet, vehicle designers are still experimenting, testing, and perfecting. Suspension is a major factor in relation to performance, safety, comfort, stability, steering, tire and gas mileage, and body life, and so designers continue to work toward perfecting suspension systems. This perfecting process applies to conventional steel leaf and coil springs and all other known possibilities.

The most recent innovation in suspension is the so-called air suspension ride developed for General Motors Truck and Coach Division passenger coaches and introduced on some models in 1953. This production system uses compressed air as a suspension medium and incorporates eight flexible nylon tire fabric bellows.

To understand the place which air suspension fills in meeting this basic vehicular requirement, it is necessary to consider some of the factors involved in an ideal suspension system and to consider how the system evolved for coaches fulfills these specifications.

Air Suspension Development

Before any development is considered for production, the designer must make certain that the change he contemplates is worth-while. It was therefore necessary to submit the new air suspension system to a series of rigorous tests. The new suspension was operated in different models of coaches over all types of city streets and open highways with many observers. At the same time it was necessary to operate a conventional vehicle over the same routes for the purpose of comparison. Here a great deal of dependence was necessarily placed on personal opinion to determine the quality of the ride. Personal opinion itself, however, is a highly unknown and exceedingly variable quantity. Hence, the only approach to a correct answer was to average the opinions of a large number of people over a large number of operating conditions.

The air suspension system was tested with many different combinations, including various designs and arrangements of bellows and axle positioning means. The development of the leveling valve, the mechanism which controls the flow of compressed air to and from the bellows, required many different designs before a practical device was obtained. This valve is described below.

To determine the durability and service life of the various units in the suspe sion system, a total of nearly 50,000 mil was accumulated on the Belgian Blo road, the roughest course in the Gener Motors Proving Ground, near Milfor Michigan. This was in addition to co siderable routine laboratory testing. Th air suspension system was installed an tested on eight different vehicles before production release was made.

After checking riding comfort an durability, studies were required on effect of the new suspension system upo such characteristics as steering, brakin roadability, and tire life, all of whi could be determined only on the road.

Suspension Requirements

The fundamental requirement of coach suspension system is to provid mental and physical comfort and safe for the passengers and driver. At on time engineers thought the rate "change of velocity" caused riding di comfort. But early experimentation i reducing the rate showed this was on partially true, for lowering the rate pr duced the same effect on some passen gers as the slow roll of a pitching ocea liner.

Through the ages, the average huma being's internal organs have becom accustomed to the motion from walkin at the rate of two to three miles per hou with approximately a 30-in. step. Con verting two miles per hour to steps pe minute gives a rate of 70.4 oscillation per minute, and three miles per hou simplifies to a rate of 105.6. This concep was presented as early as 1923 befor the Institution of Automobile Engineers Most contemporary pleasure cars ar designed with a suspension frequency o from 60-90 oscillations per minute. Th automotive industry has found that an

*Air-bellows rubber springs, developed by Firestone, replace metal springs in a new General Motors bus, producing an unbelievably soft, smooth ride. Air pressure is maintained from the bus's compressed-air brake system. Because compressed air increases its resistance the more it is compressed, there is no limit to the spring's ability to absorb loads and jolts; it never "hits bottom." Tests by GM engineers indicate that the new spring, made of supertough synthetic rubber reinforced with nylon tire fabric, will last the life of the bus.

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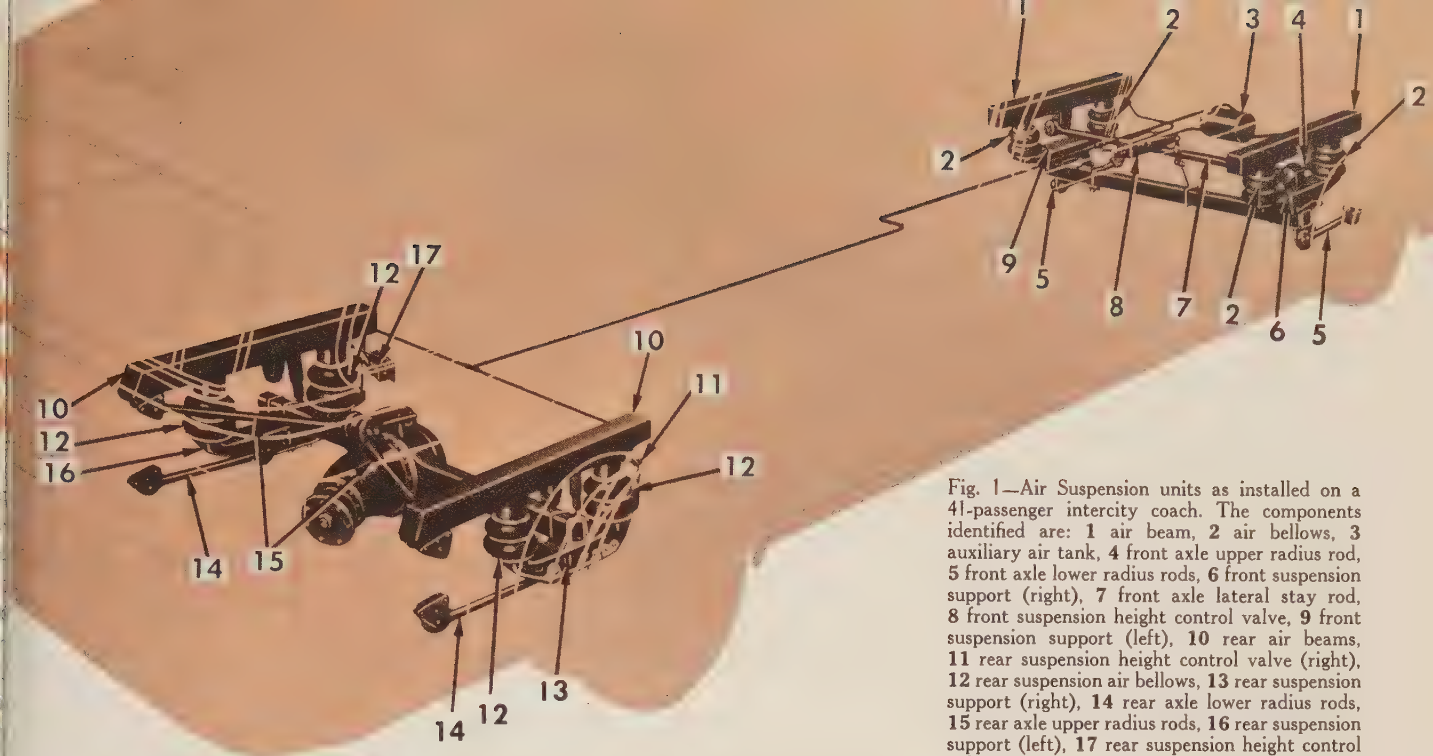

Fig. 1—Air Suspension units as installed on a 41-passenger intercity coach. The components identified are: **1** air beam, **2** air bellows, **3** auxiliary air tank, **4** front axle upper radius rod, **5** front axle lower radius rods, **6** front suspension support (right), **7** front axle lateral stay rod, **8** front suspension height control valve, **9** front suspension support (left), **10** rear air beams, **11** rear suspension height control valve (right), **12** rear suspension air bellows, **13** rear suspension support (right), **14** rear axle lower radius rods, **15** rear axle upper radius rods, **16** rear suspension support (left), **17** rear suspension height control valve (left).

frequency appreciably lower than 60 causes nausea for some passengers and unsatisfactory control. Any appreciably higher number of oscillations per minute than 90 produces a hard jarring ride.

Any change of mass in a body affects the kinetic energy of that body. To illustrate:

where $E = \frac{mV^2}{2g}$

E = kinetic energy
m = mass
V = velocity
g = acceleration due to gravity.

As the body weight m decreases, its ability to resist force without changing its horizontal position is decreased. An example of this fact is the easier ride in a full coach as compared to an empty coach with conventional steel springs.

Comfort

The most desired type of suspension is one that keeps the same number of oscillations per minute regardless of the load. This insures a comfortable ride whether the coach is full or empty.

Another feature of an ideal coach suspension is its ability to provide the necessary mechanisms to diminish succeeding motions of the chassis caused by stored energy in the suspension and moving parts after the wheel has passed over road irregularities.

The most advantageous suspension system is one that should eliminate any sizeable amount of friction. This is necessary for two reasons: *friction of rest* is greater than *friction of motion* and *friction of rest* varies with climatic and lubrication conditions. With a large amount of friction, small movements of the unsprung portion of the vehicle cause heavy vibrations to the sprung mass because the heavy friction of rest must be overcome before even a slight flex of the resilient means occurs. Thus, when larger movements occur, heavy friction at the beginning causes large disturbances which result in very rapid acceleration or lurch.

Safety

The safety of the passengers and the operator is of prime importance in the consideration of a coach suspension system. Steering, car control, and suspension are correlated so that one cannot be discussed without the others. Steering is understood to mean the control that the driver exercises over the vehicle—his ability to cause the vehicle to travel in the desired direction with ease and safety. It also includes the ability of the vehicle itself to maintain a straight course and return to a straight course when it has been disturbed in any way. This control, exercised by the driver, is transmitted through the steering gear, the linkage, the suspension, and the tires.

The ideal suspension has the important job of keeping the axles positioned properly. Axles should move up or down with respect to the body. Lateral, longitudinal, or torsional movements are to be avoided. Any of these three may have an unfavorable effect on ride, tire wear, and most important, on steering geometry and vehicle control. For instance, if the rear axle is allowed to turn slightly on its axis *understeering* or *oversteering* may arise and disturb the steering geometry. Understeering is a condition in which a vehicle, being directed into a turn or operated on by a lateral force, tends to travel at a greater radius. Oversteering is a condition in which a vehicle, if headed into a turn or operated on by a lateral force, for example, a side wind, tends to steer itself into the direction of this force. Both of these conditions require extra movement of the steering wheel to maintain the desired radius of turn. Both disrupt ideal steering geometry. Both increase driver fatigue by decreasing the ability of the vehicle to maintain a straight course without assistance from the driver, and increasing the amount of force required at the hand wheel for turning corners.

Material

Material for suspension systems must have maximum elasticity—it must have long life when flexed through a given cycle that does not exceed its physical

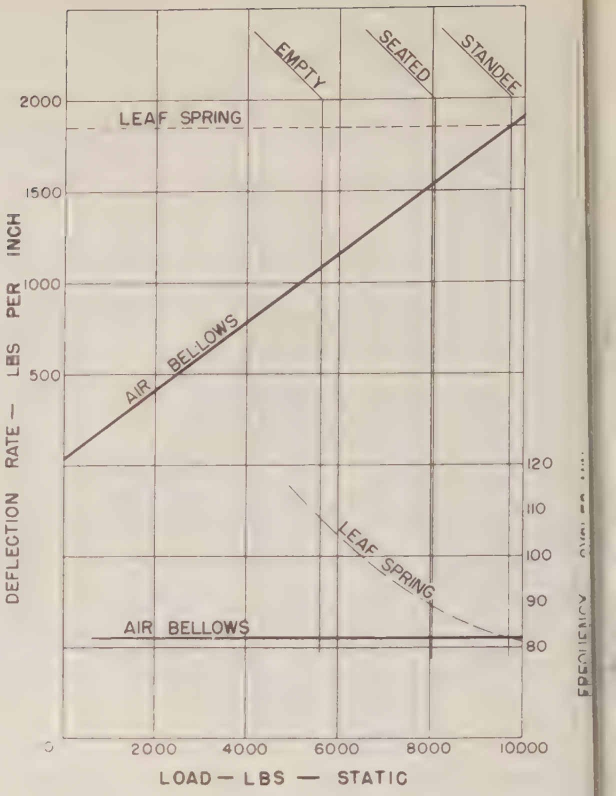

Fig. 2—Comparison of rate and frequency, at various loads, of air suspension and metal leaf spring systems in 51-passenger transit coach.

properties. Another requirement is that it be able to deflect through a given cycle without permanent deformation, especially in the vertical direction. It must have stable physical properties so that whether the temperature is below 0° F. or at 100° F., it has substantially the same suspension characteristics. Also it must be relatively unaffected by the actions of mud, water, and salt. Low maintenance cost is a desirable factor.

How Air Suspension Meets These Requirements

With the requirements of an ideal suspension in mind, engineers devised the air suspension system. Air suspension system is logically named for the compressed air which acts as a cushioning medium between the vehicle and the axles. Air is contained in four air beams (Fig. 1), two at each axle. Mounted below each air beam are two rubberized nylon cord bellows which serve as flexible connections between the frame and the axles.

Rubber

The air suspension system designers decided to use rubber in their new system because it is perhaps the most flexible, elastic, mobile, inert matter known for practical use. Rubber has no initial friction to overcome in flowing and flexing and it is silent. In this service, rubber wears very slowly, whereas alloy steel, used in spring suspension systems, has a certain fatigue limit. Tests with the air suspension system over a period of ten years show no appreciable wear. Air suspension lasts the life of the coach. Rubber requires no lubrication or care and is resistant to salt, grit, and grease. Important for use in a suspension system, rubber has the ability to absorb every degree of shock.

Aside from the bellows, rubber is used in other parts of the air suspension system. To do the best possible job of keeping road and axle noises out of the coach body, the axles are completely insulated from the body. No metal-to-metal contact exists between axle and body. Torque rods, sway bars, shock absorbers, and leveling valve links incorporate bushings of rubber in their connecting ends. The bellows of rubberized fabric insulate the axles from the body.

Compressed Air

The compressed air in this system is supplied to the leveling valve which, in turn, meters it to the suspension system. Engineers recognize that compressed air makes an ideal suspension medium by virtue of its nature and characteristics. Compressed air responds to the slightest vibrations. It gives maximum benefits in the high frequency vibration range. Because there is no friction to overcome with compressed air, it responds instantly to the slightest axle movements, even those caused by the tread of the tires. Compressed air makes possible a *progressive rate* of deflection (Fig. 2).

The air suspension system allows little friction. With high-friction suspensions there is a heavy resistance on small bumps when little resistance is desired and little resistance results when high resistance is desired. The result of an impact with a high-friction suspension is comparable to the impact of striking an anvil with a hammer. With frictionless suspension systems it is more like the impact that occurs when a heavy piece of rubber is placed on the anvil before striking. The force is the same in both but the resistance is different.

In the air suspension system practically all friction is eliminated and shock absorbers can be designed to control only excessive axle movements such as occur on washboard roads. This leaves the suspension system practically free on normal road surfaces and provides th optimum in soft ride.

The compactness of the air suspensio system makes possible the design of shorter-turning-radius steering system The turning ability on GMC coach with the air suspension system installe is improved two to three and one-ha feet through center-type steering (axle- mounted) and installation of front, ai suspension assembly.

Radius Rods

In the air suspension system the tas of keeping the axles positioned properl is assigned to a system of radius rods (Fig. 1) which are designed to minimize the movement of the axles with respect to the body except, of course, for purely vertical movement. These rods maintain the positions of each axle against any lateral, longitudinal, or torsional movements.

Low Maintenance Cost

Installation of the air suspension system reduces maintenance costs. Spring replacement is eliminated since there is no metal fatigue. The air suspension system is permanently noiseless. All the joints have rubber bushings so no lubrication is required. The air suspension system has a long life. Body stress is re-

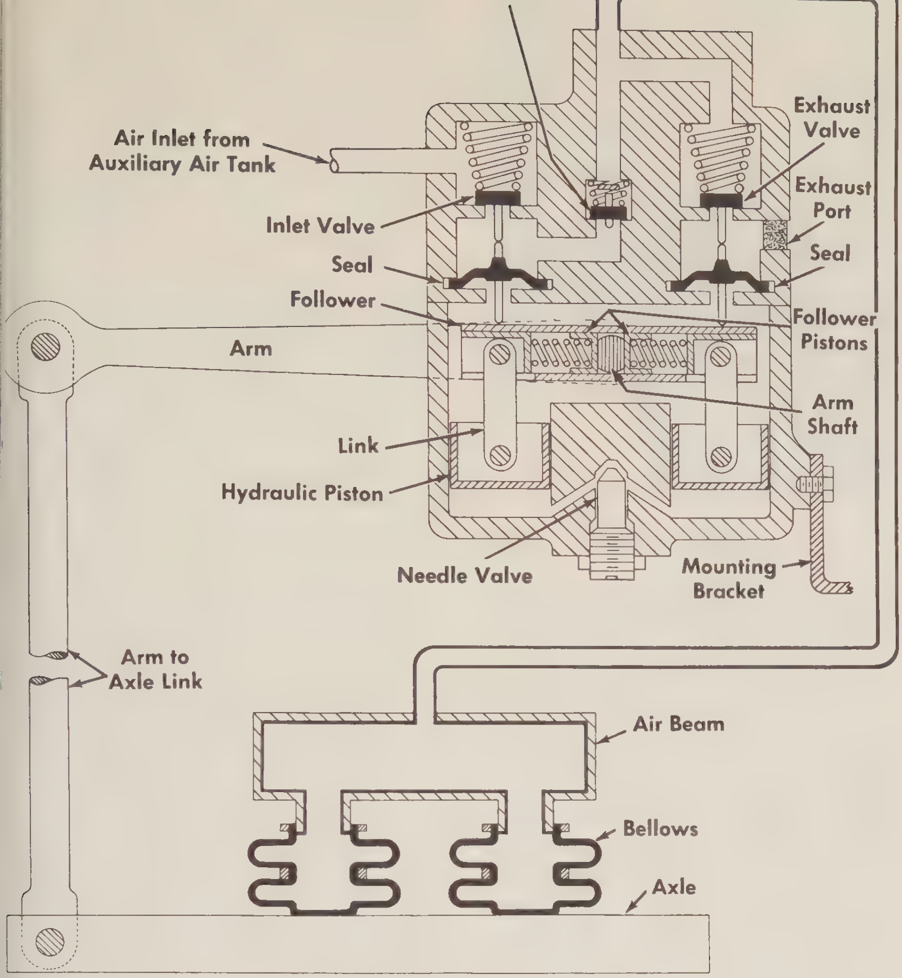

Fig. 3—A schematic diagram of the leveling valve which controls the intake and release of the compressed air.

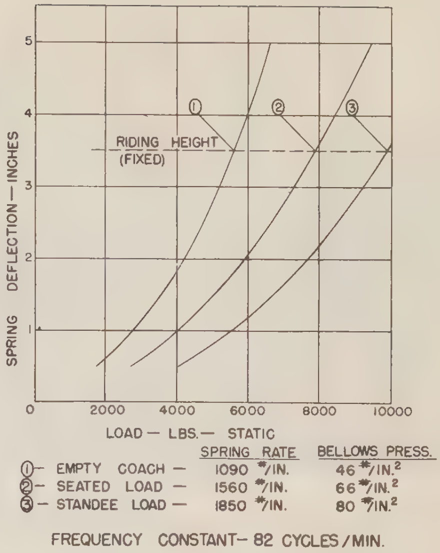

Fig. 4—Plotted lines showing deflection characteristics of a 51-passenger transit coach equipped with one pair of rear bellows.

duced because the air suspension system absorbs most of the shocks completely.

Advantages of Air Suspension

Following are the principal advantages of the air suspension system:

(a) It eliminates the disadvantages of high frequency, low amplitude vibration, and inconsistent ride control especially under light load conditions.

(b) It limits the duties of the load carrying member to suspension only.

(c) It provides a constant body height above ground, an important feature in a motor coach where legal requirements dictate a certain maximum step height.

(d) It provides an excellent sound insulating device absorbing most tire, wheel, gear, and brake noises before they reach the coach body.

(e) It reduces maintenance by eliminating metal-to-metal joints which require lubrication.

(f) It results in a considerable reduction of stresses in the vehicle body and chassis structure because it reduces or eliminates many of the high frequency loads transmitted from the axles to the body and chassis in a metal suspension system.

(g) The nylon cord bellows have a low flex stress and tests indicate their life will be much longer than conventional metal springs.

Special Features of Air Suspension

Leveling Valve

The most critical component of the system is the leveling valve. There are three mounted on the coach body frame, one in the front and two in the rear of the vehicle (Fig. 1). The function of these valves is to maintain the correct riding clearance between body and axles. To illustrate, as passengers board the coach, the gradual increase in weight causes the bellows to flex and the loaded body settles toward the axles. As this happens, the axle connecting link rises and forces the arm to rotate in a clockwise manner as shown in Fig. 3. This rotation forces upward the inlet valve. The exhaust valve remains in a closed position. The air from the auxiliary air tank rushes in through the air inlet, its pressure forcing open the check valve, and rushes down the air feed line through the air beam into the bellows. The bellows expand and the increased air pressure returns the coach body to its original position.

Conversely, as the passengers leave the coach and the load is decreased gradually, the body of the vehicle rises. This rising causes the connecting link to lower and the arm to rotate in a counterclockwise motion. This movement of the arm forces the exhaust valve open while the inlet valve remains locked. The compressed air in the expanded bellows, discovering an outlet, rushes through the air feed line, past the exhaust valve, and out the exhaust port (Fig. 3). The bellows deflate and return the body to its original position with respect to the axles.

Thus, the body is always maintained at a fixed position with respect to the axles, regardless of load, and the flex rate is always directly proportioned to the load. This results in constant frequency and the same riding quality regardless of whether the coach is empty or loaded (Fig. 4).

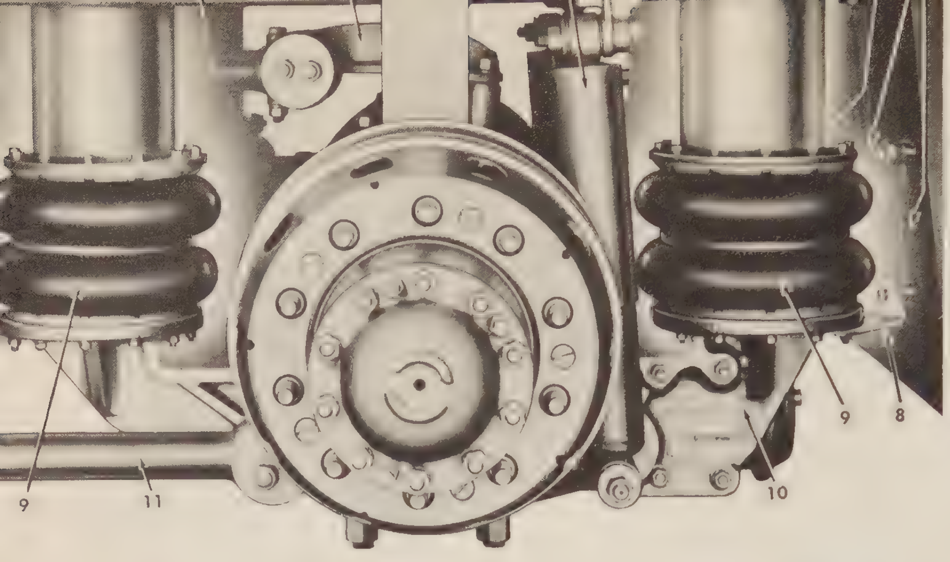

Fig. 5—Close-up of air suspension installed on the rear axle of a 41-passenger intercity coach. The identified components are: **1** air beam, **2** upper radius rods, **3** upper radius rod anchor bracket, **4** shock absorber, **5** height control valve, **6** height control valve arm, **7** height control valve link, **8** height control valve link bracket, **9** air bellows, **10** suspension support, **11** lower radius rod.

Another important function has been designed into the leveling valve. It never admits or exhausts air except when the load is changed gradually. Normal movements of the axles which occur when the coach is moving over rough road have no effect on the leveling valve. This function is accomplished by means of a damping device so arranged that the valves do not operate except when the change in distance between axles and body is very slow and steady such as occurs when loading or unloading a coach.

Most of the shock from a quick change, such as in road irregularities, is absorbed by the rubber bellows. Any sudden change moves the arm and causes the arm shaft to pivot and move one of the hydraulic pistons. The needle valve is designed to restrict the rate of liquid according to the needle valve adjustment. This slows the action of the piston. The inlet and outlet valves react only with slow and steady loading. The pistons and needle valve act as dampers and react to any sudden shocks.

Radius Rods

In the air suspension system radius rods maintain the positions of each axle against lateral, longitudinal, and torsional movements (Fig. 1). These torque rods are equipped with rubber bushings at each end to absorb shock and road noises and to eliminate the necessity for lubrication. Rods are mounted in a fore and aft direction above and below each axle to absorb the longitudinal forces resulting from driving and braking as well as the components resulting from bumps. These rods also absorb axle torque developed by driving and braking. Lateral bars keep the body centered over the axles when the vehicle is rounding a curve or driving on a side slope. This method of axle positioning results in a safety feature. Independent of the bellows condition, the axles are always held in their proper location; thus, in all cases, assuring the driver of complete vehicle control.

Bellows

The four sets of bellows with their accompanying air chambers are another important part of the system (Fig. 5). Each of the four air chambers consists of a rectangular rubber-lined sheet steel box with large openings into two rubberized nylon tire fabric bellows mounted below it, forming a single compartment of compressed air.

These eight bellows act as a flexible connection between the coach body and the axles. The flexing of the air bellows results in increasing and decreasing pressures in the air chamber which act to absorb road shocks in the same manner that an inflated rubber tire cushions shocks from road roughness.

Conclusion

Air suspension of vehicle bodies has taken 12 years of development for its specific application to GMC coaches. It is a mechanical device which is base on sound principles of physics but, a with many advances in industry, its development included empirical approache which precluded a knowledge of th basic theories involved. In essence, th development required a knowledge o the behavior of air under pressure, rubber under stress, and a knowledge o what a human passenger would consider an ideal frequency of vertica motion as the vehicle passed over al conditions of highways.

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The Relationship of Organizational Structure to Production Cost Reduction Activity

By ELMER A. RICHARDS
and ARTHUR B. WRIGHT
Allison Division

Cost Reduction Committee preserves quality in seeking economies

Maximum production economy, without sacrifice of quality and performance, is the goal of all competent engineering. Yet when a product has been manufactured successfully for four years, how can the technical thinking and action of the development-production team reduce costs even more? One way is to review current practice involved in manufacture and subject this practice to intense study by a committee representing each organization function. A typical application of this technique of specialized inter-functional analysis and action led, at Allison Division, to remarkable production cost reduction on a vehicle transmission. The transmission's 101 Allison-manufactured parts were subjected to scrutiny, and 287 proposals for improved methods of manufacture resulted.

During a period of rising material and labor costs, the problem of product cost becomes increasingly acute. Industrial management would prefer to hold the price line without impairment of either the quality of the product or the profit from the operation. Such an accomplishment is possible only if sufficient variables exist in the design of the product and in the manufacturing operations. When a large number of variables can be brought to light and adequate skill and experience are brought to bear on them, it is possible to interrelate these variables in such a manner that maximum economy is achieved.

An understanding of the location and nature of the variables is necessary in approaching the problem. The origin of the variables appears to be in the basic structure of the organization, organization here meaning the people whose task it is to carry the product through from beginning to completion.

The conventional organization of an industrial operation handling a group of related products is essentially a functional one. This is the case because the functional organization probably fulfills the overall requirements better than any other arrangement. The general functions of an operation might cover Departments for Engineering, Processing, Material Procurement and Handling, Standards, Tooling, Production, and Inspection. Such an organization is shown schematically in Table I. The functional Departments are listed vertically and their contribution is shown symbolically horizontally, or left to right.

An organization of this type is designed to maintain a desirable consistency of function between products. The nature of its operation develops some degree of standardization within each functional group. Engineering designs and approaches are carried from one product to another and thus effect standardization on an informal basis. Precedent is established and tends to be maintained until interrupted by external effect. This phenomenon is at work within each of the functional groups, from product to product, A through D in Table I.

The relationships existing between functional groups are indicated in a *vertical* direction in Table I. These relationships are handled on a formal basis by forms and procedures which are an integral part of most organizations. These are expressed with drawings, route sheets, tool layouts, and printed schedules. A formal human tie is established by higher levels of management, but this tie is concerned primarily with administration and is not ordinarily as strongly in effect at the operating level.

Random contact is maintained by individuals in each of the functional groups as problems arise. Such contacts are ordinarily limited to the gathering of sufficient information *only to resolve the problem at hand*. When any of the functions are completely interrupted, a meeting of the responsible heads of the affected groups is called and sufficient information and activity is brought to bear to resolve the problem and allow operations to resume.

It becomes apparent that the *vertical relationships* among the functional Departments listed in Table I are important

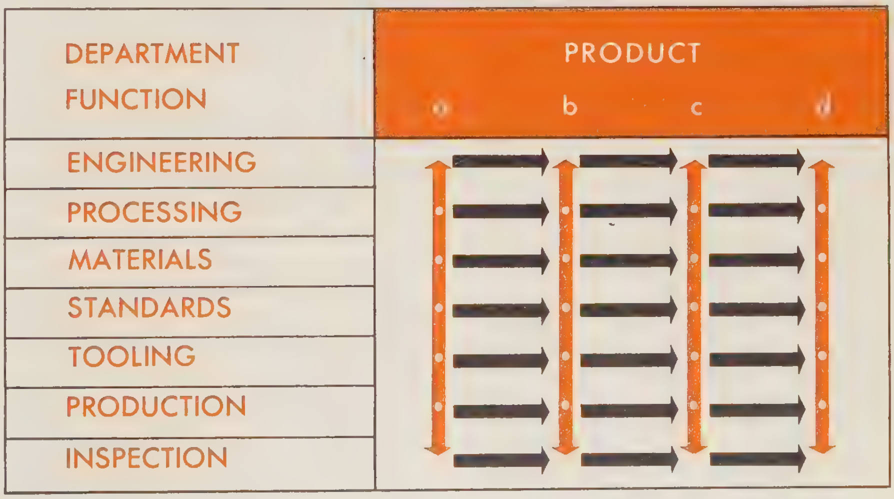


Table I—Each function associated with a product's manufacture usually is well coordinated horizontally within itself. Often improved cost performance can result from closer coordination *vertically*, among all of the functional Departments.

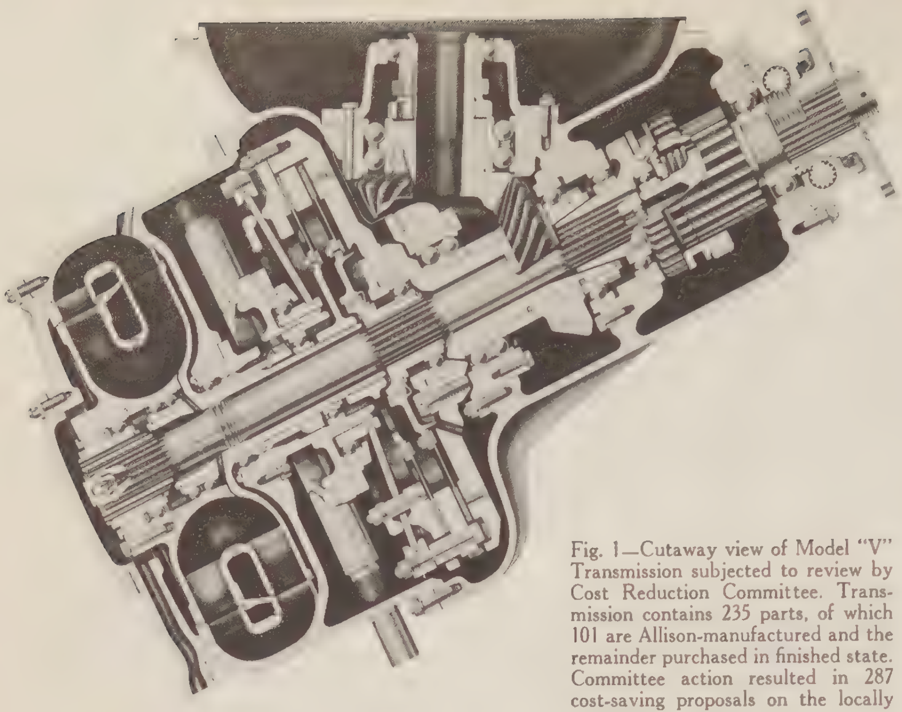


Fig. 1—Cutaway view of Model "V" Transmission subjected to review by Cost Reduction Committee. Transmission contains 235 parts, of which 101 are Allison-manufactured and the remainder purchased in finished state. Committee action resulted in 287 cost-saving proposals on the locally manufactured parts.

and that this area can suffer from lack of attention simply because forms and procedures are not capable of self-correlation, although the activities within each functional Department may be well correlated. In other words, forms and procedures do not think. Thus, when the *vertical relationships* require revision, they must be given human attention.

The same factors which underlie the normal operational difficulties in an industrial organization also affect the product cost. It is highly probable that a large number of factors exist in the relationship of functions which affect product cost but do not result in *apparent* operating difficulties.

From such an approach it would appear that the variables would be most effectively sought by exploring the *vertical relationships* shown in Table I as these relationships affect a product.

Model "V" Transmission and a Committee

A case example of the functional-relationship approach was the cost reduction program undertaken experimentally on the Model "V" Transmission at the Allison Division by a *Cost Reduction Committee*. The particular product involved was the power transmitting unit (Fig. 1) used on city and cross-country coaches manufactured by GMC Truck & Coach Division. The design of the unit, called the Model "V" Transmission, was directed toward conservation of space, service accessibility, and rugged dependability. The Model "V" has 235 parts, of which 134 were, and are, purchased in the finished state. The unit provides for forward operation through a high-torque-ratio hydraulic converter and an automatic direct drive. Manual shift is required for reverse. The use of the transmission in normal service requires for speed control, only foot operation of the accelerator and brake pedals. No auxiliary operation of either is required to obtain proper shifting of the transmission unit. (This allows the driver to handle the fare collection as well as the driving function.)

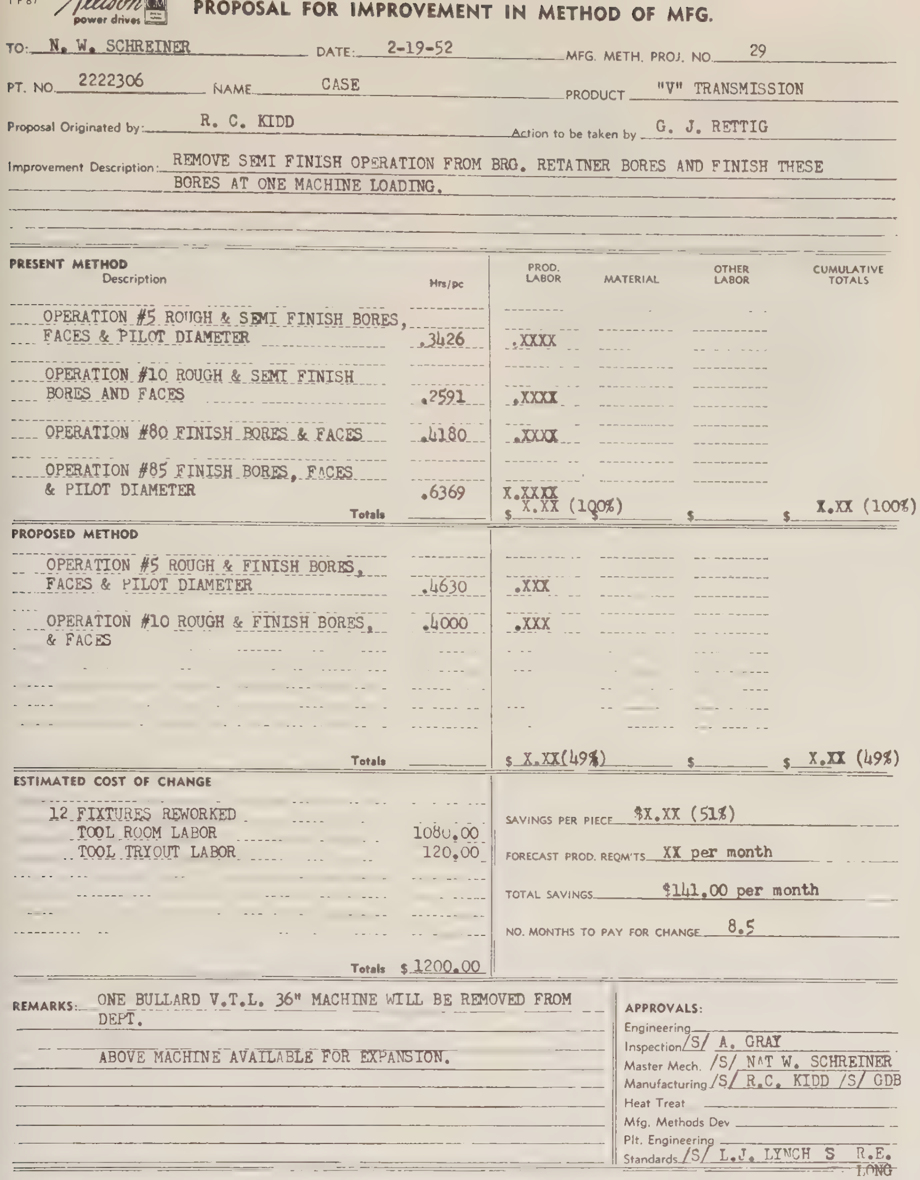
When the Cost Reduction Committee went to work, the unit had been in production for some four years. The difficulties incidental to the beginning of operations had been eliminated and the general improvement in cost of operations associated with the acquiring of experience on the job had leveled off.

From the management standpoint, it was desirable to prevent any additional increase in cost, since the unit was a component in a product marketed under highly competitive circumstances. At the same time, schedules were at low volume due to the demand in irregular volume for city and cross-country transport equipment. These circumstances presented problems as formidable as might be expected for any cost reduction program.

The Committee was organized around representatives of the various functional groups involved in the manufacture of the Model "V" Transmission. The members were selected from among supervisors close to the operating level. Such a selection provided information first hand and yet maintained sufficient authority to take action on certain proposals without delay. On some proposals one or more committee members consulted with functional supervisors higher in authority. Thus, the basic organizational structure of the Division was not circumvented; rather the Committee was designed to augment for a special purpose the usual working communication among the functional groups involved. After the Committee agreed unanimously, with some of its members having sought supervisory guidance, a proposal was put into effect.

Engineering was represented by a production engineer, and Processing by a process engineer. Material Procurement nominated a specifications man on special assignment. The time study analyst responsible for work standards and machine loading on the transmission represented the Work Standards Department. The tooling viewpoint came from the general foreman and the foreman of Tool Try Out. The general foreman of the Model "V" Transmission Production Departments represented Manufacturing. Spokesmen for Inspection were the general foreman and the foremen of the Transmission Inspection Departments. Chairman of the committee was a methods engineer of the Manufacturing Methods Development Department. This selection had the natural advantage that the methods engineer, in the course of normal work, maintained close liaison with all of the functional Departments involved.

The Committee agreed to operate according to a three-point policy. The points were: (a) there must be no revisions which impair the performance or durability of the unit; (b) every revision should be accepted or rejected on an economic basis as related to the final cost of the product, and (c) when revisions are questionable, relative to quality or performance, the experimental approach is to be used to obtain factual information.



PROPOSAL FOR IMPROVEMENT IN METHOD OF MFG.

TO: N. W. SCHREINER DATE: 2-19-52 MFG. METH. PROJ. NO. 29

PT. NO. 2222306 NAME CASE PRODUCT "V" TRANSMISSION

Proposal Originated by: R. C. KIDD Action to be taken by G. J. RETTIG

Improvement Description: REMOVE SEMI FINISH OPERATION FROM BRG. RETAINER BORES AND FINISH THESE BORES AT ONE MACHINE LOADING.

PRESENT METHOD Description	Hrs/pc	PROD. LABOR	MATERIAL	OTHER LABOR	CUMULATIVE TOTALS
OPERATION #5 ROUGH & SEMI FINISH BORES, FACES & PILOT DIAMETER	.3426	.XXXX			
OPERATION #10 ROUGH & SEMI FINISH BORES AND FACES	.2591	.XXXX			
OPERATION #80 FINISH BORES & FACES	.4180	.XXXX			
OPERATION #85 FINISH BORES, FACES & PILOT DIAMETER	.6369	X.XXXX			
Totals		$ X.XX (100%)	$	$	$ X.XX (100%)

PROPOSED METHOD	Hrs/pc	PROD. LABOR	MATERIAL	OTHER LABOR	CUMULATIVE TOTALS
OPERATION #5 ROUGH & FINISH BORES, FACES & PILOT DIAMETER	.4630	.XXX			
OPERATION #10 ROUGH & FINISH BORES, & FACES	.4000	.XXX			
Totals		$ X.XX(49%)		$	$ X.XX (49%)

ESTIMATED COST OF CHANGE	
12 FIXTURES REWORKED	
TOOL ROOM LABOR	1080.00
TOOL TRYOUT LABOR	120.00
Totals	$ 1200.00

SAVINGS PER PIECE $X.XX (51%)

FORECAST PROD. REQM'TS XX per month

TOTAL SAVINGS $141.00 per month

NO. MONTHS TO PAY FOR CHANGE 8.5

REMARKS: ONE BULLARD V.T.L. 36" MACHINE WILL BE REMOVED FROM DEPT.

ABOVE MACHINE AVAILABLE FOR EXPANSION.

APPROVALS:
Engineering
Inspection /S/ A. GRAY
Master Mech. /S/ NAT W. SCHREINER
Manufacturing /S/ R.C. KIDD /S/ GDB
Heat Treat
Mfg. Methods Dev
Plt. Engineering
Standards /S/ L.J. LYNCH S R.E. LONG

Table II—Adaptation of actual "Proposal for Improvement in Method of Manufacturing" affecting the Model "V" Transmission. This change was adopted and the extra equipment cost amortized in eight and one-half months of subsequent manufacture. The part involved is shown in Fig. 3.

The Committee operated throughout the area indicated *vertically* in Table I. Each part in the transmission was considered separately. The items in each function were studied and related to the other functions. *That this was productive is indicated by the fact that 287 proposals for improvement in method of manufacture were submitted on the 101 parts which are produced at Allison.* The proposals for improvement fell into four familiar categories of economy: (a) product design and engineering specifications, (b) material, (c) tooling and equipment, and (d) manpower and/or motion.

The analysis of the individual parts took a number of forms. Prominent among them was a well-known methods engineering approach consisting of four steps:

(a) Search for the *indicator* of a problem and define the problem.

(b) Determine the cause of the problem.

(c) Determine an economical proposal for elimination of the problem.

(d) Put the proposal into effect.

By use of this approach, every production *problem* became an opportunity for improved cost performance. Even when there were no indications of a problem, the Committee reviewed and questioned each operation and its related items of product design and manufacturing procedure. Suggestions came from each functional group and many were subjected to cost analysis at the Committee meetings. Other suggestions required further investigation in order to reach a decision. Assignments were accepted by Committee members to expedite such correlation of information.

For each proposal for improvement, the affected portions of the product cost were calculated for the proposal and compared with the current costs. The cost of the change was introduced and the time required to pay for the revision was calculated. This figure was considered the prime factor in accepting or rejecting the proposal.

Table II shows a typical proposal involving tooling and equipment changes which resulted in a saving in production costs. By combining a semi-finish operation with a finish operation, the unit cost was reduced by 51 per cent. This proposal, like all the others, was carefully evaluated from the standpoint of man hours required and the estimated cost of the change, and the number of production months which would be required to amortize the additional equipment cost through savings in unit production savings.

Product Design and Engineering Specifications

In addition to the overall design of a product, the individual component parts are defined in engineering drawings. Each drawing is the designer's concept of the best means of fulfilling a particular function of the product. The designer's choice is affected by his experience—his familiarity with processes, materials, and methods. In addition, the proposed schedule for production and the facilities and abilities of the local manufacturing organization may require modification of the drawing. Though the original choice may have been optimum on the date of its release, subsequent developments in any of the above factors could alter the situation.

The process used may determine the cost of the design to a greater extent than any other single factor. Since the design and manufacturing process are so intimately related, and since the process has such a pronounced effect upon manufacturing cost, it is desirable to treat the two as a combination rather than separate items. The choice of processes is

Fig. 2—Output shaft hardness specification was reduced from 45 Rockwell "C" to 32-36 "C" and its manufacture was simplified and made less expensive without diminished efficiency nor durability of the shaft.

always affected by the fact that one process is inherently lower in cost than another. For example, forming metal into a functional shape by means of dies is less expensive than by melting the metal and allowing it to flow into the desired shape in a mold which must be rebuilt for each individual piece. Thus the approach to the problem might be contained in the question, "How can this process be incorporated into a design to fulfill the required function in the product?" Because both engineering and processing people were represented on the Cost Reduction Committee, and because the combination of design and processing were questioned, a number of such proposals resulted.

Several covers and brackets, previously cast or forged, were found to be more economical as stampings. In a number of cases, it was necessary to test transmissions having the proposed new parts to determine whether or not the lower cost design was acceptable. This was often expressed by the statement, "Let's see how the transmission likes it!"

Individual items on the engineering drawing were often found to have considerable effect on costs. For example, the output shaft (Fig. 2) was designed to be very hard (45 Rockwell "C"). This confined the processing to the following sequence: (a) heat treat for machinability; (b) machine all over; (c) harden and draw; (d) straighten, and (e) grind.

In addition to the considerable number of times that the part was handled, it was found that many parts were being scrapped because the straightening operation could not always be accomplished properly. Questioning the 45 Rockwell "C" hardness brought to light that this was considered necessary by the designer to obtain adequate fatigue life. Several shafts at 32 Rockwell "C" were compared with standard shafts on fatigue tests. In every case the shafts of lower

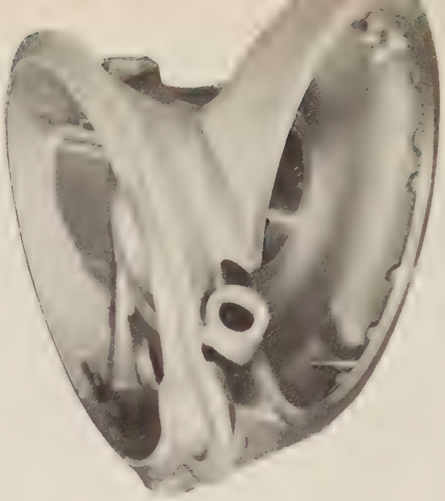


Fig. 3—Two operations were found to do the work of four on this Model "V" Transmission case at a resulting saving of 51 per cent per unit, as pointed out in Table II.

hardness were found to exceed the fatigue life of the hardened and ground shafts. The design specifications were changed to a hardness range of 32-36 Rockwell "C" which allowed the entire machining to be done with heat-treated raw material. This eliminated the straightening and grinding operations as well as the high scrap losses experienced with the original shaft.

Of the 287 proposals on the 101 parts, 61 per cent involved changes in product design or specification.

Material

A substantial portion of the finished-piece cost is represented by the cost of the raw material. Caution must be used in the analysis of raw material costs because of the relationship of the raw material properties to costs in other functional areas. It is possible that a *decrease* in raw material costs can produce an *increase* in finished piece cost. Often it is possible to achieve the opposite effect where the finished-piece cost is lowered by allowing an increase in raw material costs and thereby reducing subsequent processing or tooling costs. In general, the material cost component is affected to a considerable degree by the selection of the material to be used and by the selection of the process by which the raw material is prepared prior to receipt in the plant.

In the Model "V" cost reduction program, the use of bronze and brass construction on an oil inlet pump screen was questioned. It was found that the material selection had been influenced by a desire to avoid corrosion difficulties, and to effect ease of fabrication. Since the screen was submerged in oil, and since steel screens had successfully found many uses in automotive engines, a proposal was submitted for revision of material and minor elements of design. Acceptance of the proposal was expedited by Committee action and a significant saving was realized.

An example of the effect on-cost of the preparation of raw material was encountered in the case of the transmission's sump pan. The original design could be made only by casting in a sand mold. The Committee proposed that use of a permanent mold would result in a lower material cost per piece, and, in addition, less machining would be required on the casting produced by the process. Accordingly, engineering design modifications were made to provide for the use of the lower-cost raw material. The necessary assignments to prepare for the modifications were made by Committee action and the proposal was subsequently accepted.

While proposals involving raw material costs totaled only ten per cent, as compared to 61 per cent involving product design and specifications, the savings in material cost subsequently have proved to be substantial.

Tooling and Equipment

Tools and equipment can be considered adjuncts to the processing of the part. The *vertical relationship* in Table I between processing and tooling is similar to the relationship between product design and processing in that the specification of the sequence of operations defines the character of the tooling.

In the handling of this relationship, the process sheet represents the process engineer's best choice of a variety of means for obtaining the required end result.

This choice is influenced by information available, personal experience, and apparently personal preference factors. The latter can assume great importance. Committee exploration of the relationship between processing and tooling brought to light new information, correlated existing information, developed proposals for cost reduction, and resulted in scheduling the necessary action.

Table II, discussed above as a general example of cost reduction, shows specifically how a saving was effected through changes in tooling and equipment. In the Model "V," a sequence of operations important for bevel gear alignment had been in effect on the precision machining of bores and their corresponding mounting faces in the main case (Fig. 3). The sequence was: (a) rough and semi-finish bores and faces in one axis; (b) rough and semi-finish bores and faces in second axis; (c) semi-finish and finish bores and faces in first axis; and (d) semi-finish and finish bores and faces in second axis.

While these operations were not considered a problem, Manufacturing proposed to eliminate the semi-finish operations and two operations were substituted for the four, as follows: (a) rough and finish bores and faces on first axis, and (b) rough and finish bores and faces on second axis.

Evaluation of this proposal indicated that the change would pay for itself within eight and one-half months and would free a 36-in. vertical turret lathe for other uses.

Tooling and equipment proposals amounted to 24 per cent of the 287 changes.

Manpower and Motion

The economic and effective use of human effort and time are in the province of the Methods Engineer. The analysis of the cycle times on various operations is often productive. Where the machining cycles cause operator waiting time, operations can often be combined to effect labor savings. The elimination of hand work by mechanization can also be accomplished in many cases.

In the Model "V" investigation, a situation was encountered where a cutting fluid had to be added to a precision boring operation to obtain a suitable surface finish. When this addition was originally made, the operator was provided with a railroad type oil can (Fig. 4). A revision of the machine to incorporate a pump allowed the machine operator to do a hand drilling operation during the machine cycle. This had been done later in the sequence of operations.

Of all the proposals, five per cent directly involved a reduction in manpower and motion.

Interrelationship of Cost Reduction Factors

Most of the examples used to illustrate savings in the four categories also indicate their interrelationship. A change in any one of these categories usually can be seen to affect one or more of the others and this pattern prevailed in all the proposals.

A change in design of the product to eliminate spot facing eliminates tools and equipment as well as reduces labor.

A change in material can affect tools through increased tool life and reduce machine requirements, because of increased feeds and speeds. These have an effect on labor, both direct and indirect.

Changes in tools and equipment for economic reasons can affect the tolerances which are specified on the engineering drawings, while maintaining an acceptable design.

Changes in method of doing the job are reflected in the processing, tools, and equipment. Elimination of operations such as lock wiring cap screws is an example.

The interrelationship of the factors underscores the advantages of a means for operating *vertically* through the various functions of an organization.

Summary

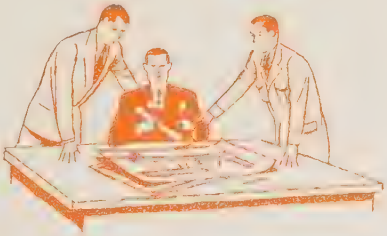
Reduction of manufacturing costs is a real problem in all phases of industrial management.

Many variables which affect product costs are related to the organization structure. In conventional organizations they may be brought to light by analysis of the inter-functional relationships.

The formation and operation of a Cost Reduction Committee to examine these interrelationships and to take proper action can result in substantial savings.

A systematic approach should be made throughout: to determine where possibilities for improvement exist, to investigate the conditions surrounding the possibilities, to develop economical proposals for improvement, and to put the proposed improvements into effect.

An application of knowledge and experience such as is represented in a Committee working within normal organizational structure assures successful progress toward the objective of reduced product cost without sacrifice of quality.



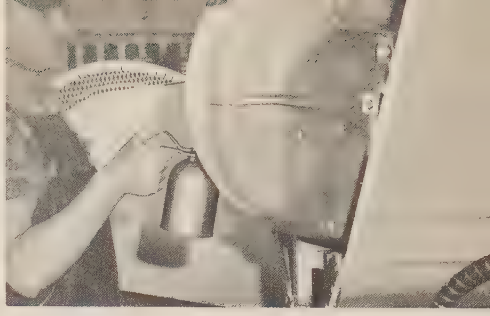


Fig. 4—The workman's problem of supplying cutting fluid from a railroad type oil can was solved by addition of a pump to the machine. This change enabled machine operator to complete a hand drilling operation which previously had been done later in the manufacturing sequence. Such small changes amounted in the aggregate to substantial savings.

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Notes About Inventions and Inventors

By **ROBERT E. FOWLER**
Patent Section
Central Office Staff

Everything worth inventing

has been invented?

Not so, records prove.

Patents are commonly referred to and everyone hears of them generally, but not many laymen, outside of those directly connected with the patent profession, know what a patent is.

Broadly, a patent is an agreement between the granting government and an inventor. In this agreement the government on its behalf grants exclusive use of the invention as defined in the claims of the patent for a prescribed period (17 years from the date of the patent in the United States) in exchange for a clear and complete description of the invention supplied by the inventor. The patent consists of a specification, claims, and drawings. The specification and drawings provide a detailed description of the invention. The claims follow the specification and point out particularly the subject matter which the inventor regards as his discovery.

The patent system of the United States is based upon a provision in the Constitution. Article I, Section 8, clause 8, reads: "The Congress shall have power . . . to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

The purpose of the patent system is therefore to "promote the progress of science and useful arts." Some reward or incentive must be held out to the inventor to encourage him to spend his time and resources to improve or create new constructions. If he felt that anyone could immediately duplicate or copy what he had done and compete with him, very little incentive would be provided to urge an inventor on.

By providing the patentee with "exclusive use" or "exclusive right" to his invention for this period, the incentive is provided. However, this does not mean that the Government of the United States will take active steps to prevent others from using a patentee's invention. It does mean that a granted patent defines in its claims an invention, and if anyone else makes unauthorized use of that invention the patentee may bring suit in the Federal courts to enforce his rights and prevent the unlawful use of his invention.

On this and the following pages are listed some of the patents granted during the period from May 1 to July 1. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

- **Donald F. Alexander**, *Frigidaire Division, Dayton, Ohio, for a Modulating Refrigerating Apparatus, No. 2,637,175, issued May 5.* The patent covers an air conditioning system which provides a control system for a reduction in refrigeration output in response to either a reduction in refrigeration requirements or a reduction in power available for operating the compressor.

Mr. Alexander has served in Frigidaire's Engineering Department since June 1930 and is now a section engineer. His projects have included the design, development, and application of motors, controls, wiring materials, and circuits to refrigeration products. He obtained the degrees of B.S. and M.S. in E.E. from University of Maine in 1923 and 1926, respectively. His work has resulted in many other patents in this field.

- **James S. Burge, Floyd J. Foust, Willard C. Shaw, Warren M. Rider, and Hilton J. McKee**, *Delco-Remy Division, Anderson, Indiana, for an Apparatus for Welding a Terminal Clip to a Wire, No. 2,637,798, issued May 5.* This patent claims a machine for attaching lead wires to terminal clips in an automatic manner wherein lead wires and clips are fed to the machine and are ejected therefrom in an attached and welded condition.

Mr. Burge is no longer with the Division.

Mr. Foust is inspection supervisor of machine tool or die design at Delco-Remy Division. He attended Purdue University. Delco-Remy employed Mr. Foust in November 1939 as an inspector. Subsequently, he was promoted to foreman in April 1943, to junior engineer in February 1945, and to his present position in June 1950. His present work is concerned with electronic equipment.

Mr. Shaw is employed at Delco-Remy as engineer—project on design. He began at this Division in 1939 as a tool making apprentice. In 1943 he was promoted to toolmaker and in 1945 he became senior designer. He was made foreman of the tool room in 1950, serving until attaining his present position in 1952. He attended Ball State University.

Mr. Rider is no longer with the Division.

Mr. McKee's biography was previously published on page 33 of the June-July 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **Robert M. Critchfield and John W. Lawson**, *Delco-Remy Division, Anderson, Indiana, for a Switch, No. 2,637,789, issued May 5.* This invention is directed to a combined engine ignition lock and hood latch release wherein the hood cannot be opened due to the locking effect on the latch unless the ignition key is in position and the ignition is unlocked.

Mr. Critchfield, general manager of Pontiac Motor Division since July 1952 and a General Motors vice president, is a 32-year veteran engineer who was Delco-Remy's factory manager when application was made for the patent. He is an electrical engineering graduate of Ohio State University. He is a member of Eta Kappa Nu, Sigma Xi, S.A.E., and the American Ordnance Association. In June 1953, he was awarded an honorary doctor of laws degree by Franklin College.

Mr. Lawson is no longer with the Division.

- **Thomas L. Kendall and Donald P. Gentry**, *Delco Battery Plant, Delco-Remy Division, Muncie, Indiana, for an Electrolyte*

Level Indicator, No. 2,637,209, issued May 5. This patent deals with an electrolyte level indicator for use with automotive batteries, which indicator comprises a rodlike body of light-transmitting material, for example, methyl methacrylate resin.

Mr. Kendall serves as chief engineer for battery operations. He earned the B.S. degree in chemical engineering from Purdue University in 1933. In January 1934 he was employed by Delco-Remy as a repairman. He served in the Army from January 1941 to January 1946, attaining the rank of lieutenant colonel. He is a member of the Society of Automotive Engineers, the Electrochemical Society, and the American Chemical Society.

Mr. Gentry has been experimental chemist in the Engineering Department since September 1948. He received the B.S. degree in chemical engineering from Purdue University in 1944 and was employed during the same year by Delco-Remy as a chemist. He is a member of the Fort Wayne Rubber Group.

- **Charles A. Nichols, Max E. Todd, William A. Fletcher, and Clarence J. Keller,** *Delco-Remy Division, Anderson, Indiana, for Apparatus for Heating Comminuted Molding Material, No. 2,637,070, issued May 5.* Powdered thermosetting resins are delivered to the surface of a heated and slowly rotating drum. After reaching a predetermined temperature, the molding material is removed from the drum and is fed to a compression chamber of a molding machine.

Mr. Nichols is factory manager of aircraft production at Delco-Remy. After receiving the B.S. degree in mechanical engineering from Carnegie Institute of Technology in 1923, he was employed by Delco-Remy as a tool designer. Three years later he became process engineer. In 1942 he was promoted to supervisor of process and tool engineering and later became master mechanic and coordinator of defense planning. His most recent promotion, in 1952, made him factory manager.

Mr. Todd is senior engineer at Delco-Remy. He was originally employed by Delco-Remy in March 1941 on assembly work in the Production Department. Subsequently, he was made junior designer in June 1943, senior designer in October 1944, and senior engineer in May 1953. He attended the University of Cincinnati. His current work is with plastic molding machines and heat sealing machines.

Mr. Fletcher, chief process engineer at Delco-Remy, is a 1930 graduate of General Motors Institute in Flint, Michigan. His GM employment began in 1926 at the Chevrolet Division in Flint. In September 1928 he was transferred to Delco-Remy and was promoted successively through junior engineer, senior engineer, and staff engineer. His past projects include work on pole shoes, generator shafts, and extruded frames.

Mr. Keller has retired from his position with Delco-Remy Division.

- **Brooks H. Short,** *Delco-Remy Division, Anderson, Indiana, for Apparatus for Testing Dynamoelectric Machines, No. 2,637,204, issued May 5.* This invention relates to an apparatus for testing motors whereby the speed-torque curve of the motor is traced on a cathode ray oscillograph where it may be compared with a given standard for a motor of that type so that any manufacturing imperfections may be quickly determined.

Mr. Short is staff engineer at Delco-Remy. He received both the B.S. and M.S. degrees in electrical engineering from Purdue University in 1931 and 1934, respectively. He was employed by Delco-Remy in December 1936 as a junior engineer and became senior engineer in August 1943. He is a member of the S.A.E. Electrical Equipment Committee.

- **Howard T. Walther,** *Inland Manufacturing Division, Dayton, Ohio, for Method for Injection Molding, No. 2,637,073, issued May 5.* This invention relates to a method for joining elastomeric strip material. Two end portions of the strip are spaced in a divided mold and then vulcanizable rubber-like material is injected into the mold through a cut-off valve. The entire mold is heated to vulcanize and bond the injected material to the end portions of the strip.

Mr. Walther is master mechanic in Inland's Tool Department. He was originally employed by this Division in April 1932, as a tool, die, and mold maker. From this position he advanced to mold making foreman in March 1936, to production engineer in February 1942, and finally to his present position in March 1945. His technical affiliations include membership in the American Society of Tool Engineers.

- **Napoleon P. Boretti,** *Fisher Body Division, Detroit, for Lubricator for Pneumatic Tools, No. 2,638,182, issued May 12.* This patent relates to a device for injecting small quantities of oil in atomized form into an air pressure line that is used to operate various pneumatic tools. Provision is particularly made for adjustments necessary through variations in pressure drop in the line.

Mr. Boretti is assistant engineer-in-charge of development engineering, Process Development Section, Detroit. He joined Fisher Body in March 1938 as a designer and advanced to his present position in July 1953. He received the B.S.E.E. degree in 1935 from University of Detroit, where he also studied mechanical engineering for two years. He is a member of the American Welding Society and the American Institute of Electrical Engineers.

- **Harold J. Schoelles,** *Harrison Radiator Division, Lockport, New York, for a Control Device, No. 2,638,015, issued May 12.* The patent relates to a push-pull type of control device for heaters and other apparatus adapted to be mounted on the instrument panel of the vehicle and more particularly to a device for resiliently holding the device in different positions of adjustment.

Mr. Schoelles is senior project engineer—supervisor at Harrison Radiator, where he started as a tool room apprentice in 1934. After a few months, he became a draftsman and continued in this position until 1944 when he was made senior project engineer. Four years later, he became supervisor of design, which post he held until assuming his present position in January 1952. His current projects are concerned with car heater and air conditioning design.

- **Edwin G. Sprung,** *Chevrolet Motor Division, Detroit, for a Brake Lever, No. 2,638,017, issued May 12.* This patent is directed to a detent mechanism for a foot-operated emergency brake lever used on Chevrolet trucks. The mechanism consists of an arcuate rod pivoted to the brake lever which passes through an eye in a detent lever which is universally

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

pivoted to provide for self-alignment between the arcuate rod and the detent lever.

Mr. Sprung is assistant chief engineer in charge of truck chassis engineering. He joined the Engineering Department as a designer in February 1929 and advanced to project engineer in June 1933, division engineer in May 1943, assistant staff engineer (chassis) in December 1946, and to his present position in June 1952. He has been a member of the Society of Automotive Engineers since 1931.

• **Carl J. Bock,** *GMC Truck & Coach Division, Pontiac, Michigan, for a Brake Drum Vibration Damper, No. 2,639,195, issued May 19.* A combination vibration damper and wheel balancing weight is attached to the brake drum and has a friction-material pad which contacts the wheel rim to damp the brake drum vibration and eliminate squealing. The weight may be adjusted to balance the wheel.

Mr. Bock has been GMC's chief engineer since January 1947. He attended Iowa State College majoring in mechanical engineering. In 1925, Yellow Cab, Yellow Coach, and General Motors Truck Company amalgamated and Mr. Bock was placed in charge of truck design and development. His technical affiliations include the S.A.E. and the Engineering Society of Detroit. He serves on the GM General Technical Committee and the S.A.E. Truck and Bus Technical Committee.

• **Eric S. Carlson,** *Fisher Body Division, Detroit, for an Ash Receiver with Mounting Plate, No. 2,639,055, issued May 19.* This patent covers an ash receiver for attachment to the rear portion of a seat back that has a concealed but readily detachable connection to the seat back.

Mr. Carlson was originally employed in 1928 by the Ternstedt Division as a designer on body hardware. In July 1945 he was transferred to the Engineering Department of Fisher Body to become a member of the Trim and Hardware Styling Section until his death in 1949.

• **Oliver K. Kelley,** *General Motors Engineering Staff, GM Technical Center, just north of Detroit, for a Fluid Control for Rotary Turbine Type Hydraulic Torque Converters, No. 2,638,746, issued May 19.* The invention pertains to the oil system supply for a fluid torque converter, particularly for controlled flow through a cooler and through the converter working space, having a thermostatic valve as one of the flow regulator controls.

Mr. Kelley is engineer-in-charge of transmission development at the GM Technical Center. He earned the B.S. degree from Chicago Technical College in 1925 and he studied automotive engineering at Massachusetts Institute of Technology during 1926-27. He started with GM as a detailer at the Cadillac Motor Car Division in 1927. He is a member of the Front End Geometry Committee of the S.A.E. and is chairman of both the Captured Enemy Equipment-Transmissions Committee and the Hydrodynamic Drive Nomenclature Committee of the S.A.E.

• **Archie D. McDuffie and Warren H. Smith,** *Research Laboratories Division, Detroit, for a Force Measuring Apparatus, No. 2,638,781, issued May 19.* This patent relates to dynamometer means for measuring torque by the use of fluid pressure. It provides a balancing of a force-measuring arm against a fluid pressure; the reading of the fluid pressure at the balance value indicates torque.

Mr. McDuffie is an assistant department head of the Research Division's Automotive Engines Department. He began his GM career in September 1931 at Cadillac Motor Car Division, Detroit, as a cooperative engineering student from General Motors Institute. Upon being graduated in product engineering from GMI in 1934, he joined the Research Laboratories Division. He is a member of the Society of Automotive Engineers.

Mr. Smith is supervisor of the design group of the Mechanical Development Department. He received the B. S. degree in mechanical engineering from Purdue University in 1928. His technical affiliations include membership in the Society of Automotive Engineers, the American Society of Mechanical Engineers, and the Engineering Society of Detroit.

• **Carel F. Abresch,** *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,639,600, issued May 26.* This patent for an automatic washing and extracting machine describes a rotatably mounted washing container with a clothes squeezing diaphragm having as its salient feature a liquid loop circuit with a jet pump connected to the outlet of a centrifugal pump.

Mr. Abresch has been senior project engineer in Frigidaire's Appliance Engineering Department since May 1948. He served in the Royal Netherlands Navy from August 1939 until January 1945 as a marine engineer, leaving with the rank of lieutenant senior grade. He attended the Institute of Technology, the Netherlands, and is a member of the Society of Naval Architects and Marine Engineers.

• **Max G. Bales,** *Delco-Remy Division, Anderson, Indiana, for a Ventilating System for Sealed Ignition Distributor and Engine Crank Case, No. 2,639,701, issued May 26.* This patent deals with a ventilating system for engine crank cases and ignition distributors used on vehicles which are subjected to intermittent water submersion. A sealed distributor is provided which is vented into the crankcase.

Mr. Bales has been a staff engineer assigned to military equipment since April 1949. After earning the B. S. degree in electrical engineering from Purdue University in 1933, he was employed by Delco-Remy and was designated as a student engineer. In June 1939 he became a junior engineer, and in October 1942 was promoted to senior engineer. He is a member of the Society of Automotive Engineers.

• **John W. Dyer and Raymond A. Wilkins,** *Delco-Remy Division, Anderson, Indiana, for an Ignition Timer, No. 2,640,116, issued May 26.* This patent deals with an ignition timer of the type which is adjustable automatically in accordance with engine suction. This invention is basically directed to the operation of a diaphragm device for yielding greater diaphragm movement upon decrease in engine suction.

Mr. Dyer is a research engineer at Delco-Remy. He attended both Purdue and Tri-State College and received the B. S. degree in electrical engineering in 1941. He was employed by Delco-Remy in June 1937 as a draftsman and was promoted, in October 1942, to special tester and, in February 1946, to research engineer. He served in the Navy from November 1942 until February 1946.

Mr. Wilkins is experimental engineer at Delco-Remy. He was originally employed by this Division in January 1926 as a laboratory technician. Since then he has been promoted through the positions of assistant supervisor and senior engineer. He earned the B.S.E.E. degree from Purdue University in 1924. He served in the Army from 1940 to 1945 and was separated with the rank of major.

- **Millard E. Fry**, *Frigidaire Division, Dayton, Ohio, for a Broiler, No. 2,639,659, issued May 26.* This patent describes a sheet metal broiler pan having embossed lower ledges in its front corners and the center portion of its rear wall and embossed upper ledges in its rear corners and the center portion of its front wall. A sheet metal grid is adapted to rest alternately upon either the upper or lower set of ledges.

Mr. Fry is senior project engineer. He earned the B.S. degree in mechanical engineering from University of Pittsburgh in 1931 where he was a member of Sigma Tau, honorary scientific fraternity. In July 1931 he was employed by Frigidaire as a student-engineer-in-training. He was promoted through research engineer, materials and process engineer, and appliance engineer to his present status.

- **Howard M. Geyer**, *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Fluid Pressure Actuator and Locking Means Therefor, No. 2,643,642, issued June 30.* The patent relates to a fluid pressure operated, self-locking actuator. The actuator includes a cylinder having disposed therein a piston capable of fluid pressure actuation in either direction. The piston includes a rod to any load device, and a nut which threadedly engages a screw shaft rotatably journaled within the cylinder. A dog tooth brake is provided for restraining rotation of the screw shaft and locking the actuator piston against movement.

- **Howard M. Geyer and Donald K. Ferris**, *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Motor-Driven Actuator, No. 2,639,625, issued May 26.* The patent relates to a motor-driven linear actuator. The actuator includes a motor-driven screw shaft threadedly engaging a slideably mounted but nonrotatable nut connected to a telescopic tubular member to transmit longitudinal motion.

- **Howard M. Geyer and Norman J. Bullock**, *Aeroproducts Operations of Allison Division, Dayton, Ohio, for an Actuator, No. 2,642,752, issued June 23.* This patent relates to an electric motor-driven linear actuator and covers a modification of the arrangement for obtaining linear movement shown in patent No. 2,639,625, mentioned above.

Mr. Geyer serves as chief research engineer. He earned the B.S. degree in industrial engineering from University of Alabama in 1940. He joined Aeroproducts in August 1940 as a junior draftsman and advanced through the positions of designer, senior designer, and senior project engineer to his present status. At present he is concerned with dual-drive servo control mechanisms.

Mr. Ferris now serves in the Test Department of Aeroproducts, where he is engaged mainly in the design of test equipment for regulators, propellers, and actuators. He was formerly with Frigidaire Division. Much of his work at Frigidaire was devoted to military projects, and resulted in development of portable airport landing lights and *Austempering* heat treat equipment. He attended Hobart College and is a member of the Engineers Club of Dayton.

Mr. Bullock has served as project engineer since September 1951. In January 1942, he was transferred from Frigidaire Division to Aeroproducts where he worked as a draftsman for two years before entering military service for four years in the Navy, specializing in tool engineering. In 1946 he entered University of Cincinnati as a co-op student in mechanical engineering, and, after obtaining his B.S.M.E. degree in 1950, rejoined Aeroproducts.

- **Herman L. Hartzell**, *Delco-Remy Division, Anderson, Indiana, for a Method of Making a Shock Absorbing Connection, No. 2,639,496, issued May 26.* This method for making a shock absorbing connection between a drive shaft and a driven shaft comprises a spline on one shaft with a splined socket on the other. A rubber member is placed in stretched condition over the shaft as the shaft is inserted into the socket whereupon the rubber member is released to completely fill the space between the spline and its socket.

Mr. Hartzell's biography and photograph were previously published on page 63 of the June-July 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **James O. Helvern**, *Moraine Products Division, Dayton, Ohio, for a Brake, No. 2,639,787, issued May 26.* This patent relates to an improved brake construction whereby the diameter of the brake can be held to a minimum size. This is accomplished by utilizing cooperating pairs of brake shoes in side-by-side relationship to give a greater area of shoe engagement with the drum that is slightly wider than the normal brake drum.

Mr. Helvern serves as senior layout man in Moraine's Engineering Department. He was initially employed by this Division as draftsman in August 1938, and was promoted to junior layout man in April 1940, and senior layout man in December 1940. He earned the B.A. degree from Wittenburg College in 1927. Two patents have resulted from his work on automotive brakes and brake boosters.

- **Elmer Olson**, *Rochester Products Division, Rochester, New York, for a Carburetor, No. 2,639,907, issued May 26.* This patent covers a carburetor having a fuel supply passage of specific design for conveying fuel from the float chamber to the inlets which supply fuel to the mixture passage. The passage is designed to prevent the formation of vapor bubbles of sufficient size to cause irregularity in fuel flow.

Mr. Olson has been chief engineer of Rochester Products since his employment in October 1945. He attended the Lewis Institute in Chicago. At present, he is concerned principally with studies on carburetion and fuel handling devices. He is a member of the Carburetor Flanges Committee and the Standardization Committee of the Society of Automotive Engineers.

- **Brooks H. Short and John W. Dyer**, *Delco-Remy Division, Anderson, Indiana, for an Engine Starting Apparatus with Generator Separately Excited During Starting, No.*

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

2,640,163, issued May 26. This invention is directed to an electrical system for automotive vehicles including an engine driven shunt-field generator, a storage battery, a cut-out relay for the generator and battery, a starting motor, and a number of manually operated switches for controlling operation of the engine.

Mr. Short's biography appears under patent No. 2,637, 204, issued May 5 and listed earlier in this section.

Mr. Dyer's biography appears under patent No. 2,640,116, issued May 26 and listed earlier in this section.

- **Brooks H. Short and Argyle G. Lautzenhiser,** *Delco-Remy Division, Anderson, Indiana, for an Intensifier, No. 2,640,174, issued May 26.* This patent deals with a spark intensifier adapted for use with a spark plug, including a pair of conductors providing a gap of greater length than the spark plug gap and a third electrode to provide a teaser gap spaced from the other conductors. A metal body is attached to the third electrode so that its capacity to ground is greater than the capacity of the teaser gap.

Mr. Short's biography appears under patent No. 2,637,204, issued May 5 and listed earlier in this section.

Mr. Lautzenhiser is research engineer at the Delco-Remy Division. He earned the B.S. degree in electrical engineering from Tri-State College in 1940. After his employment by Delco-Remy in December 1940 as a laboratory technician, he was promoted to special tester in October 1942 and to research engineer in August 1948. He served in the Army from April 1944 until April 1946.

- **Abraham M. Babitch,** *AC Spark Plug Division, Flint, Michigan, for a Fuel Pump, No. 2,640,424, issued June 2.* The invention relates to a fuel pump designed for variable stroke operation. A lost-motion connection is provided to give a variable stroke to the pump diaphragm, the length of stroke being determined by the pressure on the diaphragm.

Until the time of his death in 1950, **Mr. Babitch** was fuel pump engineer at AC Spark Plug Division. He had been an employe at AC Spark Plug for more than 25 years, and he was active in the initial development of the fuel pump and its subsequent improvements.

- **Floyd J. Boyer,** *Allison Division, Indianapolis, Indiana, for a Fuel System, No. 2,640,423, issued June 2.* This patent covers a fuel supply system for aircraft gas turbines. The system has main and auxiliary pumps in series, the auxiliary pump normally being by-passed so as to run unloaded but being cut in upon failure of the main pump by an automatic valve in the by-pass.

Mr. Boyer is group project engineer in turbo-propeller engine controls. He received the B.S. degree in mechanical engineering from Georgia School of Technology in 1940 and was employed by Allison as a junior test engineer. He advanced through the positions of detail engineer, experimental engineer, and project engineer in engine control design to his present position. He is a member of Pi Tau Sigma, S.A.E., and he is a registered professional engineer in Indiana.

- **Robert N. Falge and David Paul Clayton,** *Guide Lamp Division, Anderson, Indiana, for an Electrical Connector Having a Spring-Biased Line Terminal, No. 2,640,970, issued June 2.* This patent relates to an electrical connector for connecting line and lamp terminals together. The connector is made of insulating material and has passages into which one line terminal and one lamp terminal are inserted. The terminals are secured by special springs.

Mr. Falge has served since September 1937 as chief engineer at Guide Lamp. He was originally employed by GM in January 1927 by the Research Laboratories, Detroit. He received a degree in electrical engineering from University of Wisconsin in 1916. He serves on important committees on vehicle lighting in the S.A.E., Automobile Manufacturers' Association, and the National Committee on Uniform Traffic Laws and Ordinances.

Mr. Clayton serves as junior designer in the Engineering Department at Anderson. Since joining the Division in October 1939 as a paint rack repairman, he also has served as model shop crib attendant, apprentice model maker, model maker, and draftsman. He became a junior designer in December 1951.

- **Hans O. Schjolin,** *GMC Truck & Coach Division, Pontiac, Michigan, for a Fluid Actuator Clutch Control, No. 2,640,368, issued June 2.* The invention relates to a special torque converter clutch actuator mechanism and its controls. The clutch air servo device is arranged to route the air stream so as to prevent the sucking in of outside air laden with dust.

Mr. Schjolin has served as a new-development engineer in GMC's Engineering Department since 1937. He was originally employed in October 1923 as a draftsman by Yellow Truck & Coach Manufacturing Company, Chicago. Mr. Schjolin received the B.S. degree from Karlstad University, Sweden, in 1920, and from Mitweida University, Germany, in 1923. His work has resulted in several patents and published papers.

- **John B. Wheatley, Arthur W. Gaubatz, and Charles C. Anderson,** *Allison Division, Indianapolis, Indiana, for a Turbine and Compressor Stator Ring, No. 2,640,679, issued June 2.* This patent is directed to a stator vane assembly for an axial flow compressor of light, strong construction particularly suited for aircraft turbine engines. The vanes extend between inner and outer semi-circular shroud rings and are mounted by upsetting over the rings.

Mr. Wheatley serves as assistant chief engineer at Allison. He received both the A.B. degree in mechanical engineering and the master of engineering degree in aeronautics from Stanford, in 1929 and 1930. In February 1945 he was transferred to Allison from Fisher Body Division and in 1951 became assistant chief engineer. He is a Fellow of the Institute of the Aeronautical Sciences.

Mr. Gaubatz is senior project engineer in the Experimental Engineering Department at Allison. He received the B.S. degree in 1920 from University of Wisconsin. He was originally employed in September 1928 at the Buick Motor Division, Flint, Michigan, as a draftsman in the Experimental Engineering Department. He was transferred in August 1940 to Allison. He is a member of Pi Tau Sigma, and Tau Beta Pi.

Mr. Anderson is superintendent of model shop No. 2 at Allison. He was originally employed by Allison in October 1917 as an inspector. In January 1926 he became shop foreman and in January 1931 he was promoted to his present position.

- **James D. Leslie and Clyde H. Schamel,** *Fisher Body Division, Detroit, for a Door Lock, No. 2,641,495, issued June 9.* This patent covers a door lock in which the pivoted bolt may be released by a relatively light pressure operating through a push button, despite the fact that the door sealing pressure approaches 100 lb. This is accomplished by a system utilizing a detent lever and a multiplier lever.

Mr. Leslie is a senior project engineer in the Experimental and Development Section. He received the bachelor of mechanical engineering degree from University of Detroit in 1939, and was elected to Tau Beta Pi and Tau Phi engineering honorary fraternities. He joined Fisher Body in 1945 as a senior layout draftsman, became a senior designer in 1946, and assumed his present duties in 1947.

Mr. Schamel is engineer-in-charge of the Experimental and Development Section. He earned the B.S. degree in electrical engineering from University of Notre Dame in 1927. He joined Fisher Body in July 1943 as an electrical engineer on the B-29 program. He was made general supervisor in charge of B-29 drafting in January 1945, and was promoted to his present position in September 1945. He is a member of the Society of Automotive Engineers.

- **Bailey Bennett and George H. McFadden,** *Inland Manufacturing Division, Dayton, Ohio, for a Method of Making Latex Foam, No. 2,643,233, issued June 23.* This patent is directed to a method of making foamed latex wherein control of the pH of the latex prior to compounding is maintained within a desired range wherein ployvalent zinc ions are insoluble. This permits the inclusion of the zinc oxide during compounding.

Dr. McFadden has been employed since January 1944 by The Ohio State University Research Foundation as supervisor on a rubber project supported by Inland. He received the B.S. degree in 1923 from Muskingum College, the B.S. degree in pharmacy from Ohio State University in 1926, and the M.S. and Ph.D. degrees from Ohio State in 1933 and 1937, respectively. Eleven patents in the field of rubber chemistry have resulted from his work.

Mr. Bennett is no longer with the Inland-supported project at Ohio State.

- **Richard J. Brittain, Jr.,** *Hyatt Bearings Division, Harrison, New Jersey, for a Railroad Journal Box, No. 2,643,163, issued June 23.* This patent relates to antifriction journal boxes for the axles of railroad cars and is directed to a resilient end-thrust arrangement which engages the end of a car axle and absorbs sudden end-thrusts when the railroad car negotiates a curve.

Mr. Brittain serves as assistant chief engineer at Hyatt Bearings. He was originally employed by this Division in October 1921 as a designer in the Equipment Engineering Department. He is a member of the American Society of Mechanical Engineers and a past member of various committees connected with the Association of American Railroads. At present, Mr. Brittain is chairman of the Roller Bearing Manufacturers Technical Committee which acts as advisor to the Association of American Railroads.

- **Robert B. Burton,** *General Motors Engineering Staff, GM Technical Center, just north of Detroit, for a Single-Leaf Spring Clamp, No. 2,643,111, issued June 23.* This patent relates to an anchorage for a single-leaf spring for motor vehicles. The anchorage consists of interlocking clip members encircling the middle part of the spring and these clip members are secured between clamping plates that are clamped together by means for securing a spring to an axle.

Mr. Burton began his GM career in 1932 as a senior designer at Cadillac Motor Car Division, Detroit. In 1942 he was transferred to Fisher Body Tank Division, Detroit, and from August 1945 until his retirement in April 1949 he served as assistant engineer-in-charge of the Structure and Suspension Development Section, Engineering Staff, Detroit. He earned the B.S. degree in engineering in 1908 from University of London.

- **Peter R. Contant and Raymond H. Sullivan,** *Delco Appliance Division, Rochester, New York, for an Electric Clock, No. 2,642,714, issued June 23.* The patent relates to an electric clock for automobiles in which a balance wheel controls the intermittent energization of an electromagnet, and is sustained in oscillation by the intermittent energization thereof. The electromagnet also actuates a driving armature which is operable to drive the clock gear train.

Mr. Contant has served with Delco Appliance since February 1926, when he was originally employed as a blueprint room helper. Regular promotions within the Engineering Department led to his present classification as senior project engineer in charge of the development and design of automotive clocks. His previous major project work was on the development of Delco-Heat conversion oil burners.

Mr. Sullivan serves as senior research engineer in Delco Appliance's Engineering Department, which he joined in 1912 as a laboratory assistant. He is currently engaged in the development of automotive electric clocks, motors, and oil burner controls. He is a member of the Rochester Engineering Society.

- **Raymond C. Davis,** *Inland Manufacturing Division, Dayton, Ohio, for a Method of Making a Welded T-Joint, No. 2,642,652, issued June 23.* This invention is directed to steering wheels and is particularly concerned with a method for forming welded joints between the reinforcing rim and the spoke of the wheel wherein the rim is notched, as by coining, to form an outwardly extending lip upon which the spoke may rest. The spoke and rim are electrically welded under pressure for deforming the assembled portion into a flush joint of high strength.

Mr. Davis is assistant to the chief engineer at Inland. He received his mechanical engineering degree from Dayton Night College in 1920. He was employed by Inland in April 1931 as engineering designer and became chief draftsman in 1936, and assistant to the chief engineer in 1942. Before joining Inland, he was employed at the Frigidaire Division and its predecessor, Delco Light Company.

- **Lawrence C. Dermond and Ellsworth A. Kehoe,** *Rochester Products Division, Rochester, New York, for a Starter Control System, No. 2,643,347, issued June 23.* This patent is directed to a throttle-operated, starter control switch adapted to cause operation of the starting motor after the throttle makes a predetermined opening movement. A latch prevents operation of the switch when the engine is running.

Mr. Dermond has served since November 1948 as senior research engineer in Rochester Products' Engineering Department. He entered the General Motors organization in 1934 in the position of draftsman and layout with Delco-Remy. In October 1944, he transferred to Rochester Products Division as senior engineer. His technical affiliations include membership in the Society of Automotive Engineers.

Mr. Kehoe's biography and photograph were previously published on page 64 of the June-July issue of the GENERAL MOTORS ENGINEERING JOURNAL.

- **Raymond O. Doss**, *Fisher Body Division, Grand Rapids, Michigan, for a Curved Windshield and Wiper, No. 2,642,615, issued June 23.* This patent is directed to the combination of an irregularly curved windshield and the wiper-blade drive mechanism wherein the axis of the wiper drive shaft is positioned with relation to the windshield so that the wiper blade moves in a path having the least possible deviation from the curvature of the windshield.

Mr. Doss was recently made production manager at the Grand Rapids aircraft plant of Fisher Body. At the time of issuance of this patent, he was senior engineer in charge of general projects at the Fisher Body Engineering Department, Detroit. Mr. Doss joined General Motors following his graduation from Cornell in 1930 with the M.E. degree. In S.A.E., he was recently chairman of Body Activity in the Detroit Section.

- **Arthur J. Frei, Sr.**, *Inland Manufacturing Division, Dayton, Ohio, for a Freezing Tray, No. 2,642,726, issued June 23.* This patent covers a partitioned ice tray for use in refrigerators wherein three rows of ice cubes may be frozen simultaneously. Ejection of the cubes is obtained by manipulation of a handle which moves the cube dividing walls relative to the longitudinally extending walls for breaking the cubes loose from the tray.
- **Arthur J. Frei, Sr.**, *Inland Manufacturing Division, Dayton, Ohio, for a Freezing Pan, No. 2,642,727, issued June 23.* This patent is directed to a new style grid for dividing the frozen contents of the pan into individual cubes or blocks. The grid is formed of plastic wall members or partitions wherein an ejecting handle is provided for moving the partitions for breaking loose the ice held within the grid and pan.

Mr. Frei is Inland's senior project engineer, a post which he has held since January 1945. He has been employed at this Division since December 1934 when he began as a draftsman in the Engineering Department. Two years later he was advanced to designer and in 1944 he was made project engineer.

- **Argyle G. Lautzenhiser**, *Delco-Remy Division, Anderson, Indiana, for an Ignition Timer, No. 2,643,304, issued June 23.* This patent concerns an ignition timer or a distributor and is particularly directed to a novel non-wobble means for mounting the supporting plate for the circuit breaker mechanism wherein the plate is adjustable by means of a vacuum device.

Mr. Lautzenhiser's biography appears under patent No. 2,640,174, issued May 26 and listed earlier in this section.

- **John T. Marvin**, *Inland Manufacturing Division, Dayton, Ohio, for a Mold for Foamed Latex, No. 2,642,624, issued June 23.* In this invention, the bottom of the mold and the cover of the mold each includes a plurality of interfitting conical cores. Articles formed in the mold by virtue of the interfitting characteristic of the cores have substantially uniform rubber area throughout any cross section taken through the article in a plane perpendicular to the major axis of the cores.

Mr. Marvin has served since September 1937 as patent attorney in the Dayton office of the Patent Section located at Frigidaire. He handles patents from the Delco-Remy, Inland Manufacturing, and Moraine Products Divisions. He earned the B.S. degree from Case Institute of Technology in 1929 and a degree in chemical engineering from the same school in 1935. Prior to joining GM, he was chief engineer at Cleveland Heater Company.

- **William J. Rady**, *Delco-Remy Division, Anderson, Indiana, for a Starting and Generating System, No. 2,643,346, issued June 23.* This patent relates to a motor-generator system in which a dynamo electric machine can be employed as a motor to crank the engine for starting purposes or can operate as a generator driven by the engine for charging a storage battery. The device is controlled by a series of manually positioned switches.

Mr. Rady is staff engineer—product at Delco-Remy. He was employed in April 1920 by North East Electric, Rochester, New York, predecessor of Delco Appliance Division. In May 1933 he was transferred to Delco-Remy as senior engineer and in November 1945 he was promoted to his present position. He is currently concerned with carbon pile regulator development. He earned the B.S.E.E. degree in 1916 from University of California.

- **Edward J. Vosler**, *Moraine Products Division, Dayton, Ohio, for a Pressure Band for Brake Lines, No. 2,642,917, issued June 23.* This patent relates to the processing of brake shoes and particularly the manner of applying brake linings to the shoe. The fixture used in the processing applies a uniform pressure over the surface of the brake lining for uniform cement bonding of the lining to the shoe.

Mr. Vosler has served as Moraine's master mechanic since February 1943. He originally joined General Motors in June 1930 as a tool engineer at General Motors Radio. From this Division he was transferred to Delco Products and later to Delco Brake. After a six-month period at Eastern Aircraft, he returned to GM to become master mechanic at Moraine Products. He is a member of the Advisory Group for Tool Engineering at St. Clair (Y.M.C.A.) College.

- **Walter Lyman Church**, *AC Spark Plug Division, Flint, Michigan, for Electrical Apparatus, No. 2,638,496, issued June 30.* This patent relates to a temperature-compensated electrical switching relay, including bimetal means, which varies the position of the armature with respect to the coil so that the shorter the time interval between coil energizations, the less the magnetic force needed to attract the armature.

Mr. Church is research and experimental engineer at AC Spark Plug. He began at AC Spark Plug in August 1942 as testing electrician in the Engineering Department. Prior to employment at General Motors, he was with the Sparks-Withington Company, Palmer Radio and Appliance Company, East Side Radio Company, and operated a self-owned radio and electrical service shop for four years.

Recent Speaking Engagements Filled by GM Engineers

During the summer months GM engineers have continued appearing before audiences and taking part in symposiums and round-table discussions. The following report covers the period from June 1 through August 15.

General Motors personnel were very active in the General Motors Engineering Educators Conference held in Detroit from July 7 to 21. On July 8, **W. F. Andersen,** director of the Budget and Procedures Section, spoke on the "Organization of General Motors." Other speakers during the morning included: **E. L. Yates,** of the Personnel Staff, who described "Technical Personnel Activities," and **R. L. McWilliams,** of the Educational Relations Section, who outlined the "Educational Relations Program." Four speakers on the afternoon program were members of the Research Laboratories Division, Detroit. **R. A. Richardson,** head of the Administrative Engineering Department, described the "Research Laboratories Division," **D. F. Caris,** head of the Automotive Engine Department, spoke on "High Compression Engine Development," **W. A. Turunen,** head of the Gas Turbine Department, outlined "Jet Engine Developments," and **L. L. Withrow,** head of the Fuels and Lubricants Department, reported on "Combustion and Lubrication Problems in Automotive Engines." The final speaker, **G. T. Christiansen,** administrative assistant in the GM Styling Section, spoke on the "Organization and Function of GM Styling Section."

On July 9, **L. A. Walsh,** manager of Engineering Staff Activities, described "GM Engineering Staff Operations." "Engineering a New Model Car" was outlined by **G. R. Delaney,** chief engineer at the Pontiac Motor Division. **Charles A. Chayne,** Vice President in Charge of Engineering Staff, explained "The Influence of Products and Markets on Product Engineering."

The July 10 morning speakers included: **John J. Cronin,** Vice President in Charge of Manufacturing Staff, who spoke on "GM Manufacturing Staff Activities" and "The Influence of Products and Markets on Production Engineering;" **E. T. Ragsdale,** works manager at the Buick Motor Division, who described "Production Tooling of a New Car Model,"* and **R. J. Emmert,** Executive in Charge of Facilities and Processes Staff, who spoke on "Staying in Production in a Competitive Market." During the afternoon inspection-trip to the Process Development Section, located at the Detroit Cadillac plant, **Glen Fitzgerald,** director of the Process Development Section, described the "Organization and Function of the Process Development Section."

H. H. Barnes, director of the GM Proving Ground, Milford, Michigan, spoke on July 11. His topic was "The Organization and Function of the GM Proving Ground."

A trip to the General Motors Institute, Flint, Michigan, was on the agenda for July 18. Members of the Institute who made presentations were: **Guy R. Cowing,** who described the "Organization and Function of General Motors Institute," **Harold Dent,** who outlined the "Cooperative Engineering Program," **Charles Tutt,** who spoke on the "Fifth-Year Thesis Program," and **Charles Sahrbeck,** who reported on "Educational Program Development."

On August 11, **Arthur Bender,** quality engineer at Delco-Remy Division, Anderson, Indiana, spoke on "Statistical Quality Control" at the University of Michigan during the meeting of the Institute for Mathematics Teachers.

"Cooperative Education in Industry" was the title of a talk given in Washington, D. C., at the convention of the National Catholic Business Educational Association on June 21. The speaker was **Harold M. Benson,** chairman of the Business and Economics Department at the General Motors Institute, Flint, Michigan.

C. A. Brown, chairman of the English and Psychology Department at General Motors Institute, spoke before a joint meeting of the American Society for Engineering Education and the College English Association held at the University of Florida. The talk, given on June 25, was entitled "Engineering Education and the Liberal Arts."

On June 30, at the semi-annual meeting of the American Society of Mechanical Engineers, held in Los Angeles, **L. C. Lander, Jr.,** chairman of the Industrial Engineering Department at the GM Institute, outlined "An Engineering Approach to Methods Improvement and Planning."

The University of Michigan graduate speech students, on July 13, heard **Robert M. Carter,** instructor in the English Department at the GM Institute, discuss "Speech Training for Engineers at GMI."

On June 8, **David C. Apps,** head of the Noise and Vibration Department at the GM Proving Ground, Milford, Michigan, was on the S.A.E. Summer Meeting Round-table: "Noise Measuring Instruments—Haves and Have-nots."

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*The paper beginning on page 26 is Mr. Ragsdale's adaptation of his talk for the GENERAL MOTORS ENGINEERING JOURNAL.

Theodore Jagen, senior engineer in the Mechanical Development Group of the Hyatt Bearings Division, was a panel member on June 18 at the Basic Materials Conference held in New York City. Mr. Jagen's topic was "Development of Co-operation in the Selection of Materials."

The 150 high school mathematics teachers who attended the Mathematics Institute at the University of Virginia from July 27 to August 7 heard **Mario Parran,** quality control supervisor at the Clark Township Plant of the Hyatt Bearings Division, discuss the courses in mathematics necessary to enter the field of quality control. Mr. Parran's talk was entitled "Mathematics Necessary for Quality Control in Mass Production."

On July 21, **John W. Leggat,** assistant chassis engineer at the Pontiac Motor Division, appeared before the GMI senior engineering class in Flint with the topic "Steering and Handling of the Automobile."

During Northwestern University's Lubrication Engineers Short Course, **Joseph Bidwell,** assistant head of the Mechanical Development Department, Research Laboratories Division, delivered a lecture on June 17 entitled "Bearing Materials as Influenced by Dynamic Loading Conditions." On June 23, in the same series, **Arvid Roach,** supervisor of Bearing Development, talked on "Performance and Durability of Oil Film Bearings Under Operating Conditions."

In Atlantic City, **William Grube,** supervisor of the Physics of Solids, and **Stanley Rouze,** research physicist of the Physics Instrumentation Department, Research Laboratories Division, discussed "Specimen Polishing Techniques for Electron Metallography of Steel" at the June 30 meeting of the American Society for Testing Materials.

"The Engineer, a Trail Blazer" was the title of the talk given by **T. A. Boyd,** Research Laboratories consultant, at the June 20 meeting of the National Society of Professional Engineers in Daytona Beach, Florida.

Roger Saur, senior physicist in the Physics Instrumentation Department, Research Laboratories, presented a talk, "Chemistry and Physics of Paint Chalking," before the Research Directors Council on June 17 in the GM Building.

At the July 15 University of Illinois conference of the Institute of Boiler and Radiator Manufacturers, **Kenneth Robinson,** industrial ventilation engineer, delivered a talk on the "Heating and Tempering of Supply Air for Industrial Buildings."

In Atlantic City, **Harry Mougey,** technical director of the Research Laboratories Division, gave a paper on "Engine Wear as Affected by Lubricant Composition" at the July 1 meeting of the American Society for Testing Materials.

Six of the Research Laboratories Division personnel spoke at the Society of Automotive Engineers Summer Meeting in Atlantic City. **Albin Burkman,** supervisor in charge of Brakes and Clutches, on June 9, described "Prospects for Better Passenger Car Brakes." **Fred Bowditch,** senior research engineer in the Fuels and Lubricants Department, presented a paper by R. F. Winch entitled, "The Occurence of Pre-ignition in Present Day Cars in Normal Service," on June 10. **James Landis,** research chemist in the Fuels and Lubricants Department, and **Robert Williams,** assistant head of the Fuels and Lubricants Department, joined in the presentation, on June 10, of the paper "Some Effects of Fuels and Lubricants on Auto-ignition in Cars on the Road." **James Landis,** on June 11, presented a prepared discussion, written by **John Campbell,** Research Laboratories Division, of a paper entitled "Fuels and Fuel Systems —A Petroleum Viewpoint" by T. W. Wegatski, O. C. Bridgeman, E. W. Aldrich, and R. Rhode. **Harry Mougey,** technical director, took part in a Symposium on Arctic Oils on June 12. The topic of his talk was "Crankcase Oils for Use Under Arctic Temperature."

Phil Worden, process engineer at the Rochester Products Division, spoke before the American Welding Society on June 9 in Rochester, New York. The topic of his talk was "Resistance Welding as Applied to the Manufacture of Steel Tubing."

Engineering Educator Guests Take a Look at General Motors

A TWO-WEEK conference to acquaint engineering educators with the product and production programs of General Motors Corporation was conducted in Detroit beginning July 7.

Known as the Engineering Educators Conference, it was the second of its kind held by GM. Twenty-six engineering professors and department heads attended as representatives of colleges in Canada and in nearly all sections of the United States.

Charles A. Chayne, Vice President in Charge of Engineering Staff, and John J. Cronin, Vice President in Charge of Manufacturing Staff, were conference chairmen and hosts to the educators. A major phase of General Motors educational relations program headed by Kenneth A. Meade, this conference is regarded as particularly important in view of the great opportunities now existing for young engineers.

The first three days of the conference were devoted to meetings with GM divisional and staff executives who gave illustrated talks describing company policies and operations.

Typical subjects discussed were: organization of General Motors, technical personnel activities, engineering a new model car, and production tooling of a new car model. Inspection trips in the Detroit area included the Research Laboratories, Process Development Section, Styling Section, Technical Center, Proving Ground, and General Motors Institute, in Flint. Some of the papers presented at the conference have been scheduled for publication in the JOURNAL in this and succeeding issues.

The educators, after acquiring this overall view of General Motors, then scattered to various parts of the country on individual assignments to one of the GM manufacturing Divisions. In each case, the educator was afforded the opportunity to talk with the general manager, the engineers, the shop people, and many others. It was a real look at how a Division operates.

Returning to Detroit, the educators analyzed their observations in a final session with their GM conference hosts.

Shift-Rod Problem Solution

By GARRETT LOODE
Staff,
General Motors Institute

Classroom graphical method solves typical problem

Fundamental techniques taught in the nation's engineering classrooms find daily application in the laboratories. Some of the applications are complex and some are simple. For the problem presented on page 60 of the June-July JOURNAL, the application was less than complex.

A GRAPHICAL solution of the shift-rod problem presented requires first the obtaining of a true view of both the 3.00-inch radii. To obtain these true views, one must work with the knowledge that two intersecting lines determine a plane. Lines *3-4* and *4-5* of Fig. 1 determine one plane and line *4-5* and *5-6* determine the other plane. Point *3* is where line *3-4* is tangent to the 1.50-inch radius. An edge view of each of these planes is produced and a projection perpendicular to these edge views reveals the true views of the planes in question.

The edge view is obtained by using the direction of projection along some line parallel to one of the principal planes of projection where it appears as its true length.

The edge view of plane *3-4-5* is projected along the direction of line *3-4* as it is parallel to the horizontal plane of projection. Therefore, away from the top view projecting along line *3-4*, the edge view is set up by W. L. *B* with the distances being obtained from W. L. *A*. (W. L. means *work line*, also called a *reference line* or *datum plane*.) By projecting perpendicular to this edge view, the true view of the plane is obtained at W. L. *D*, with the distances for this view being taken from W.L. *C*.

In obtaining the edge view of the other plane *4-5-6*, a line *4-7* is placed in the figure parallel to the horizontal plane of projection which governs the direction in which this view is projected. Thus, using *4-7* in the top view as the direction of projection, the edge view is produced at W.L. *F* with the distances taken from W.L. *E* for this view. Projecting perpendicular to the edge view *4′-5′-6′* the true view at W.L. *H* is obtained with distances coming from W.L. *G*. With these true views, the 3.00-inch radii can now be placed in the picture and be traced back into the original views.

The true length of this rod can now be laid out along some base line. Starting at point *1*, find the distance *1-2* and the arc distance along the 1.50-inch radius from point *2* to point *3*. From point *3* move to point *W* where the curve is tangent to line *3-4;* then the arc distance on the curve from *W* to *X* is taken. Continuing from point *X*, move along to point *Y*, and from *Y* the arc distance from *Y* to *Z* is obtained. The true length is completed with the distance from point *Z* to point *6*.

The developed length of such a part is dependent upon the relative amount of stretch and compression in the outer and inner fibers as well as the manner in which the bend is formed. Not knowing the forming procedure, a close approximation of the developed length may be obtained by working with the center line. Following this method, the true length of the rod is 18.415 inches.

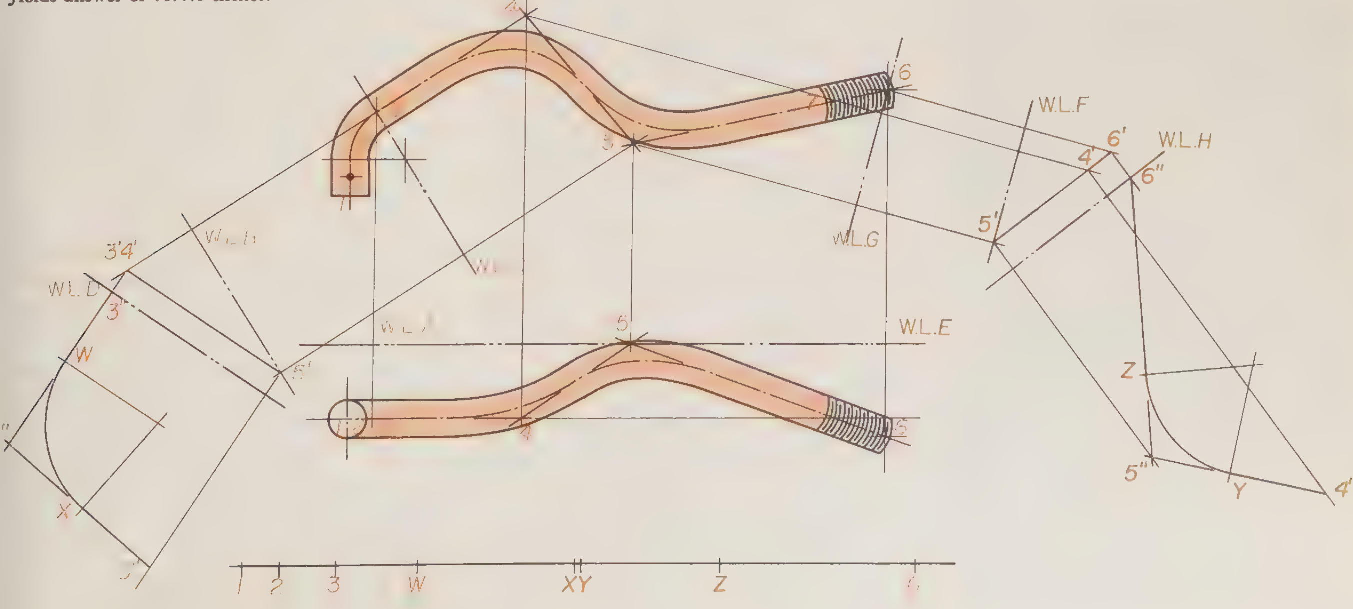
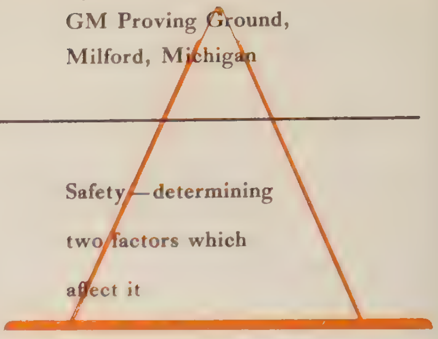


Fig. 1—Graphical solution to shift-rod problem yields answer of 18.415 inches.

A Method for Determining the Center of Gravity and Moment of Inertia of an Automobile

(Second Problem of a Series)

By REO S. BRINK
GM Proving Ground,
Milford, Michigan



Safety—determining two factors which affect it

Nature, too, has established traffic and safety norms. Some, like centrifugal force, friction, gravity, and force of impact seriously affect driving. A major responsibility of automotive testing is to aid in the production of safe, dependable vehicles that will assist the driver in modifying nature's forces. Since the height of the center of gravity and the moment of inertia of an automobile affect safe driving, engineers and mathematicians at the GM Proving Ground at Milford, Michigan, developed a method for finding these two factors by utilizing two specially constructed automobile swings. Using the data given in the text, compute the height of the center of gravity and the moment of inertia of the test car.

BOTH the height of the *center of gravity* (that point at which the total weight of the object seems to be concentrated) and the *moment of inertia* (the inertial property of an object with respect to rotatory motion) of an automobile affect driving and vehicle control. The lower the center of gravity, the less the chance exists of the automobile turning over when going around a curve. In addition, low center of gravity means less sway when the automobile is turning curves.

Inertia is the Newtonian property of all objects that causes them to resist any change in speed or direction of travel. When a car rounds a curve, its inertia attempts to keep the vehicle in a straight line, and if the friction between the tires and the road do not counteract this tendency, the car's inertia will cause it to skid.

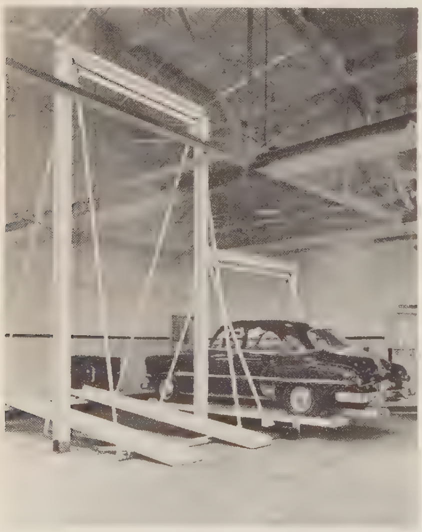


Fig. 1—Two automobile swings of unequal length constructed at the GM Proving Ground and used in tests to determine the height of the center of gravity and the moment of inertia of passenger cars.

Finding Center of Gravity Height and Moment of Inertia

To study the riding qualities of passenger cars it is necessary to determine accurately both the height of the center of gravity and the moment of inertia. The equations from an undamped compound (physical) gravity pendulum, swinging through a small arc in a vacuum, include both of these required determinations. The other values in the equations are constants or can be measured.

Realizing that a single equation cannot be solved for two unknown values, W. Howard Sprenkle, an engineer at the General Motors Proving Ground, Milford, from 1933 to 1938, proposed and developed a system of using two automobile swings of unequal lengths to obtain simultaneous equations. The expressions for the angular moment of inertia of the test car about its own center of gravity on the short swing and on the long swing can be equated. The resulting equation can be solved for an expression of the height of the center of gravity of the car. After the known values and test data have been substituted in this formula and the value of the height of center of gravity is found, this value can be substituted in the original equation for each swing to find the automobile's moment of inertia. While the equality of these values can be used to check the accuracy of the test data and the computations, it cannot be used to check the equations themselves.

Automobile Swings

Fig. 1 shows the two automobile swings of unequal lengths that were constructed for testing. The instrument on the floor near the rear wheel of the automobile contains a light source and a photoelectric cell. The edge of the plate attached to the swing oscillates between the light and the photo-cell. The resultant signal operates the recording chronograph in the cabinet ahead of the car, measuring and recording the time intervals between oscillations to the nearest 0.01 second. By averaging 600 or more oscillations, the *period* or *time required for one complete cycle* is obtained to the nearest 0.0002 second.

Experimentation has shown that the pendulum oscillates more than 600 times in an arc less than two degrees, making the effect of the amplitude negligible. The damping is less than 0.002 per cent and also can be neglected. But, due to the weight of the air displaced by and contained in the automobile, the error in the height of the center of gravity of the car varies from 0.75 to 1 in. and cannot be neglected. As it is not practical to operate a swing carrying an automobile in a vacuum, it is necessary that the equations be revised to account for the weight of the air displaced and entrapped by the automobile.

Displaced and Trapped Air

The true mass of the automobile is equal to its weight observed in air plus the weight of the air it displaces. Also considered as part of the swung mass is the entrapped air moving with the swinging automobile. This total of car weight plus air weight should be included in factors involving the moment of inertia of the pendulum, although the external forces exerted upon the car by gravity are influenced by the automobile's observed weight alone.

Two published reports on the determination of the moments of inertia of airplanes assisted in the development of the required equations. One is by S. B. Gates in the *Technical Report of the Aeronautical Research Committee of Great Britain, 1931-'32.* The second is by Harley A. Soulé and Marvel P. Miller in *Report No. 467 of 1933*, published by the National Advisory Committee for Aeronautics (of U.S.A.). Both of these reports discuss the effect of air on an airplane swung in air and present practical solutions. The latter report treats the effect of air in three parts: displaced air, contained air, and the additional mass effect. This last factor, depending on the outer dimensions of the airplane and accounting for the air along its surface which is oscillated with the air plane, is negligible on an automobile and can be omitted from the equations.

After the equations evolved for the problem have been modified for the effect of air, the height of the center of gravity of a car can be determined to within a satisfactory 0.25 in. In practice, the moments of inertia, as determined by the formula for each swing, have checked each other within 0.05 per cent. The average of the two results is used.

All of the values required to find the height of the center of gravity of a particular car in the Proving Ground swings are given in Table I and illustrated in Fig. 2. The subscript *s* denotes the short swing, subscript *l* refers to the long swing, and subscript *c* refers to the car.

Problem

Set up the proper equations and, with the values given in Table I, find the height *H* of the center of gravity of the test car, and the moment of inertia *I* of the car about this center of gravity expressed in lb-ft squared. To obtain results within the desired limits, the computations must be carried out to a higher degree of accuracy than provided for by ordinary slide rule methods.

The solution of the problem will be presented in the next issue of the JOURNAL.

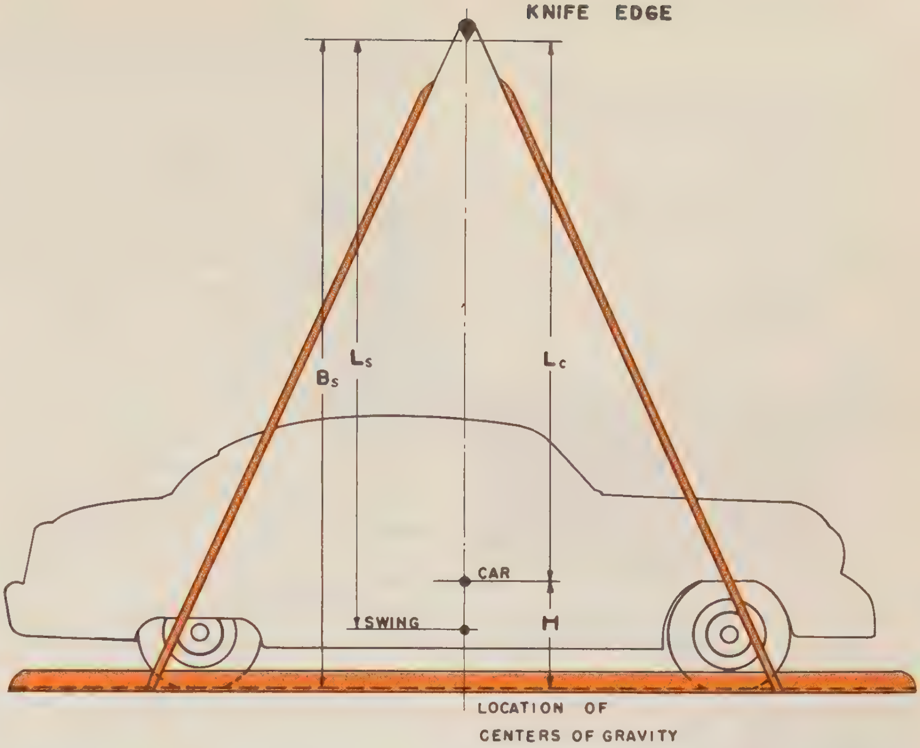


Fig. 2—Diagram of the short automobile swing. The subscript *s* denotes the short swing. *H* represents the height of the car's center of gravity, L_c represents the length from the knife edge to the automobile's center of gravity, B_s represents the distance from the knife edge to the floor of the swing, L_s represents the distance from the knife edge to the center of gravity of the swing.

Car Data

Test Weight of Car—lb $= W = 4172$

Overall Volume of Car—cu ft $= V = 297$

Periods of Oscillation—Seconds

	Short Swing	*Long Swing*
Swing Alone	$T_s = 3.5639$	$T_l = 4.5202$
With Car in Place	$T_{sc} = 3.4363$	$T_{lc} = 4.3782$

Swing Constants

	Short Swing	*Long Swing*
Weight—lb	$W_s = 1688$	$W_l = 1788$
Knife Edge to Floor of Swing—ft	$B_s = 8.234$	$B_l = 15.736$
Knife Edge to Center of Gravity—ft	$L_s = 7.40$	$L_l = 13.75$

Conditions at Test Site

Acceleration due to gravity—ft/sec^2 $= g = 32.1614$

Average density of air—lb/ft^3 $= p = 0.072$

Table I—Observed and calculated values for test car used in solving for the center-of-gravity height and the moment of inertia.

Contributors to Sept. - Oct. 1953 Issue of

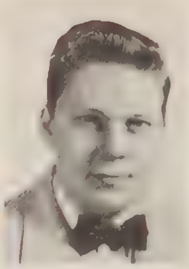
GENERAL MOTORS Engineering JOURNAL

KENNETH B. BLY,

contributor of "Use of Foam Plaster Process for Making Aluminum Alloy Torque Converter Castings," has served since October 1951 as engineer in charge of light alloy development with Fabricast Division, Bedford, Indiana. His major interests are development of processes, such as that described in his current paper, and adaptation of existing processes to new types of light alloy cast products.

Mr. Bly joined the Division in November 1948 as a supervisor of engineering planning, engaged largely in pre-production planning of pattern equipment for making aluminum castings. Before joining General Motors, he served two years as foundry manager for an Independence, Missouri, casting company and six years with Aluminum Company of America, successively in Detroit, Kansas City, and Cleveland. He began with Alcoa as a metallographer and ultimately became assistant to the chief metallurgist at the Kansas City Plant. Serving in the same capacity at Cleveland, his work included the making of permanent mold automotive piston castings.

Mr. Bly earned the metallurgical engineering degree from the School of Mines and Metallurgy Division of University of Missouri, in 1940. In 1945 he served as vice-chairman of the Kansas City Chapter, American Society for Metals. He also is a member of the American Foundrymen's Society and serves on the A.F.S. shell molding and centrifugal casting committees.



EUGENE F. COLDITZ,

contributor of "Raising the Limits for Thrust Measurement in Jet Engine Testing," has served since December 1951 as an experimental engineer in the Jet Engine Facility Group of Allison Division, Indianapolis. His current major work involves editing, writing, and publishing test equipment installation manuals, but he continues to spend considerable time on the design of equipment.

Mr. Colditz joined Allison in December 1948 as a laboratory technician in the Test Operations Group. He contributed to the design of the equipment described in his current manuscript and also worked on the design of equipment for measurement of airflow and aircraft engine fuel consumption. He also was associated with the testing of anti-icing systems for engines, part of his work being done in New Hampshire.

Indiana Technical College granted Mr. Colditz the B.S. degree in aeronautical engineering in 1948. Now a second lieutenant in the Air Force Reserve, he enlisted under the cadet training program in October 1943 and earned his wings and commission before completing active duty in 1946. He is a member of the Institute of the Aeronautical Sciences.

ROBERT R. DOHRMANN,

contributor of "Making Castings by Shell Mold and Investment Processes," has served since May 1953 as general foreman of heavy alloy inspection at Fabricast Division, Bedford, Indiana. He joined Fabricast as a project engineer in January 1951. Mr. Dohrmann earned the B.S. degree in metallurgical engineering in 1943 at Purdue University, where he was elected to Sigma Xi, honorary research fraternity.

His present duties as general foreman of inspection involve Zyglo, X-ray, visual, and gauge inspections of the heat resistant alloys used in turbine blades, vanes, and other turbine components. Mr. Dohrmann also conducts periodic customer contacts for quality control surveys.

Mr. Dohrmann aided in Fabricast's original development of the investment casting process and later worked with the shell mold process—the fields covered in his current manuscript. Earlier, he was heat-treat metallurgist in the production of precision aircraft gears and cams at the Indiana Gear Works.

From March 1944 to June 1946, Mr. Dohrmann served in the Navy, principally as an electronics officer assigned to radar maintenance. He was separated with the rank of lieutenant, junior grade.

Mr. Dohrmann is affiliated with the Society of Automotive Engineers and currently serves on the S.A.E. Shell Molding Committee.

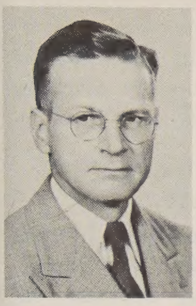
ROBERT E. FOWLER,

contributor of "Notes About Inventions and Inventors" for this issue, has served since April 1934 in the Patent Section of the Central Office Staff, Detroit. As a patent attorney he shares the Section's responsibility for providing patent protection for the novel apparatuses and processes of General Motors employes everywhere, for advising engineering organizations against unintentional infringements of the patents of others, and for negotiating royalty arrangements with non-GM companies.

Mr. Fowler's patent work has been principally in the electrical field. In his early GM years he surveyed the patent structure and did development work in the space heating electrical control field for Delco Appliance Division. This and other laboratory work has resulted in four patents. In recent years he has devoted major attention to patents affecting automotive lighting controls and automatic features of automotive radios.

At Cornell University, Mr. Fowler was elected to Eta Kappa Nu and earned the electrical engineering degree in 1926. He then was an engineer for short times in two industrial laboratories and from August 1928 until joining General Motors, he was an examiner in the U. S.

Patent Office. His work centered around patent investigations on sound recording, acoustics, and automatic train controls. During this period he earned the L.L.B. degree from George Washington University, in 1932, and was admitted to the District of Columbia bar.



HAROLD E. FOX,

co-contributor of "Air Suspension Ride: How Engineers Gave Resilience to a Compressed Air System with Rubber Bellows," is development engineer at GMC Truck and Coach Division, Pontiac, Michigan. He attended Carnegie Institute of Technology for both undergraduate and post graduate work.

Mr. Fox began his career with General Motors in December 1934 as a project engineer in the Engineering Department of GMC Truck and Coach Division. In October 1943 he advanced to senior engineer. In September 1945 he was promoted to section head engineer, and attained his present position, development engineer, in January 1947. Before employment at General Motors, Mr. Fox was executive engineer at General Aviation (now North American Aviation, Incorporated), and director of research at the Syntron Company.

His past projects in coach structural design, air conditioning, air suspension systems, and transmission development have resulted in 15 patents and 10 published papers in the fields of electrical, aeronautical, and automotive components.

Mr. Fox is a member of Alpha Tau honorary society, the Society of Experimental Stress Analysis, the Society of Automotive Engineers, and the S.A.E. Committee on Ride Research.

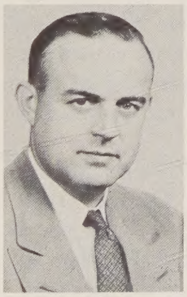
BAIN GRIFFITH,

contributor of "Gear Wheels and Applied Mathematics," was appointed in June 1952 as assistant staff engineer in Chevrolet Motor Division's Research and Development Section. He started with Chevrolet Division as a draftsman in August 1933 and in 1937 undertook a special assignment which lead to gear design research. He has become particularly recognized in this field. His gear work included the study and development of hypoid gear formulae and designs which have lead to the modern line of production rear axles. He once developed a process by which available gear cutting equipment was used to speed production of universal joints for military applications.

Three of Mr. Griffith's developments on military and passenger car rear axles have been patented. He has lectured before the American Society for Metals on hypoid gear design and production and has appeared several times on gear panels of the Society of Automotive Engineers, of which he is a member. His current paper was adapted from a lecture given at the Summer Mathematics Institute of Duke University. Mr. Griffith also has contributed to periodicals in the automotive field and now represents GM in the American Gear Manufacturers Association.

During World War II, he served as an assistant plant resident engineer and in early 1945 worked on jet engine development at Chevrolet's Tonawanda, New York, Plant. That year he became resident engineer in Chevrolet's Detroit Gear and Axle Plant, remaining there until assuming his present duties.

Before joining Chevrolet, Mr. Griffith had eight years' experience in civil engineering, which he studied at University of Pennsylvania.



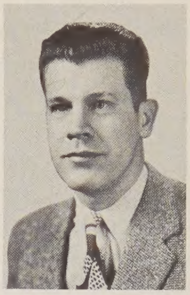
DONALD J. LA BELLE,

co-contributor of "Air Suspension Ride: How Engineers Gave Resilience to a Compressed Air System with Rubber Bellows," serves as senior project engineer in the Engineering Department of GMC Truck and Coach Division, Pontiac, Michigan.

Mr. LaBelle received the bachelor's degree in mechanical engineering from University of Detroit in 1939, and has devoted his entire engineering career to General Motors. He began in May 1939 as a junior engineer and in 1943 became a stress analyst. His promotion to project engineer came in 1946, shortly after he returned from service with the Navy. In 27 months of service he attained the rank of lieutenant, junior grade.

Besides his contributions to the present air suspension system, Mr. LaBelle has worked on structural body and chassis design and on the development of many military vehicles. His current work is on a development not yet publicly announced.

Mr. LaBelle is a member of the Society of Automotive Engineers.



GARRETT LOODE,

who prepared "A Typical Problem in Automotive Design" for the June-July GENERAL MOTORS ENGINEERING JOURNAL and its solution for this issue, is a senior mechanical engineering instructor at General Motors Institute, Flint, Michigan. Since joining the GMI staff in September 1941, his classes have included advanced projection and body drawing courses, kinematics, and gear design.

Mr. Loode received the A.B. degree in mathematics from Western Michigan College of Education in 1940 and a master's degree in industrial education in 1953 from Wayne University. His work at Wayne University as a commuting night student was completed over a five-year period.

From December 1942 to January 1946 he served in the U.S. Navy, attaining the rank of lieutenant. While in the Navy, Mr. Loode served mainly as a ship's engineering officer and in industrial relations capacities.

Prior to joining the GMI staff, Mr. Loode served briefly in technical capacities with Silvercote Products Company, Kalamazoo Stove and Furnace Company, and the U.S. Steel Products Company. He also taught for one year in public schools in Scotts, Michigan, serving as principal and as acting superintendent.

He is a member of the American Society for Engineering Education and, while at Wayne, was elected to Phi Delta Kappa graduate honorary society.

ENGINEERING EDUCATORS
For a message about the GENERAL MOTORS ENGINEERING JOURNAL, kindly see page 12.

GEORGE W. ONKSEN, contributor of "How the Autronic-Eye Automatic Headlamp Control was Designed to Meet Driver Requirements," serves as supervisor of research for Guide Lamp Division, Anderson, Indiana. His current major interest centers around development of automatic controls for headlamps, which forms the basis for his current paper.

Mr. Onksen began his General Motors career in June 1928 as an apprentice toolmaker with Delco-Remy Division, also in Anderson. He attended General Motors Institute as a cooperative student of Guide Lamp and was graduated in 1933. In October of that year he was assigned to the Engineering Department and immediately devoted his attention to solving vehicular lighting problems. He became a supervisor in June 1936.

His major contributions have been in the development of Sealed Beam headlamps and of the automatic control system of which he writes. Thirteen patents in the automotive lighting and related electronic fields have resulted from Mr. Onksen's laboratory work.

His society affiliations include membership in the Society of Automotive Engineers. He also has been elected to Alpha Tau Iota honorary society.

EDWARD T. RAGSDALE, contributor of "Putting A New Car into Production," serves as general manufacturing manager of the Buick Motor Division, Flint, Michigan. Mr. Ragsdale began his career in General Motors in 1923 as a body draftsman at the Buick Division in Flint. In July 1928 he became assistant to the body engineer and in September 1935 he was promoted to body engineer. He became assistant to the chief engineer in October 1939 and assumed his present duties in February 1949.

Mr. Ragsdale's first job was as a tool designer for the Maxwell Motor Company in Indiana, and while working for this company he studied kinematics at Indiana State Normal.

He enlisted in the Army Air Force in 1917 and served overseas as liaison officer in an engineering capacity with the British Flying Corps. His work with the British resulted in patents for a machine gun mounting and a gauge for applying flying wires and drift wires on airplanes at their proper tension. Both of these inventions were used by the British.

Shortly after his separation from military service in February 1919, Mr. Ragsdale moved from the Maxwell Motor Company to the Midwest Engine Company to become chief tool designer. Later he designed automatic machinery at the Prest-O-Lite Company and worked as a body designer for the Pierce-Arrow Motor Company. While at Pierce-Arrow, Mr. Ragsdale developed improvements on windshield and body construction which were patented.

Mr. Ragsdale's technical affiliations include membership in the Society of Automotive Engineers.

ELMER A. RICHARDS, co-contributor of "The Relationship of Organizational Structure to Production Cost Reduction Activity," has served since January 1952 as supervisor of the Manufacturing Methods Development Department of Allison Division Transmission Operations, Indianapolis.

Active in General Motors committee work for two years, Mr. Richards is the newly appointed chairman of the Central General Motors Methods Engineering Committee. He also has done committee work on torque converter fluids as a member of the Society of Automotive Engineers.

Mr. Richards was a General Motors Institute student from October 1933 until 1937, serving first on a work status with GMI's machine shop and then in the Process Department of the Research Laboratories Division. Upon being graduated, he remained with Research's Technical Data Department until July 1940, when he was transferred to Allison, initially as supervisor of that Division's Technical Data Department.

He helped administratively in augmenting the Experimental Department to handle growing military work and then undertook experimental work, part of it on an engine cold-start program. In February 1943 he became supervisor of the Components Test Laboratory and, in August 1945, became project engineer on a post-war hydraulic marine transmission, standard equipment for Detroit Diesel Engine Division's Series 71 Diesels. He was promoted to chief test engineer for Transmission Operations in December 1946 and was ordnance transmission engineer until assuming his present duties. Four of his laboratory developments have been patented.

ARTHUR B. WRIGHT, co-contributor of "The Relationship of Organizational Structure to Production Cost Reduction Activity," has served since May as an industrial engineer in the Work Standards and Methods Engineering Section of the General Motors Manufacturing Staff, Detroit. His work centers around coordination and promotion of methods engineering within General Motors. The paper was prepared before his transfer from Allison Division, Indianapolis, where he served 15 months as a senior methods engineer in the Manufacturing Methods Development Department.

Mr. Wright became a General Motors Institute co-operative student in 1934, sponsored by AC Spark Plug Division, with which he remained associated until March 1947. His degree is in industrial engineering. Upon completion of GMI course work, he served two years as an instrument repairman and then moved to the Standards Department, first to establish speeds and feeds for machines used in volume production of 50-calibre machine guns and later to supervise time study work.

From AC he was transferred to the GMI staff, where he was a senior technical instructor until February 1952, first handling time study and methods courses and then methods engineering instruction for plant personnel. During this period he served for an extended time in the Central Office Section which he now has joined as a staff member.

Mr. Wright is affiliated with the Society for the Advancement of Management, and the American Society for Quality Control has published one of his papers on statistics and time study.

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

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